Donkeys and Compost

Intermediate Transport and Soil Fertility Management in Northern Ghanaian Livelihoods

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Abstract

Sustainable livelihoods comprise complex interactions between diverse practices, facilitated by different capital use systems. Soil Fertility Management (SFM) is one such practice. Savanna farmers use organic and inorganic soil amendments. Although a strategy integrating both is most sustainable, compost use is limited by poor access to vehicles with which to carry it. This interdisciplinary study examines how SFM interacts with transport in northern Ghanaian maize smallholders' livelihoods. It asks how farmers could best transport compost and compares compost to fertiliser. It considers which of the five capitals described in the livelihoods framework facilitates the most appropriate SFM and transport strategies. Extending the livelihoods model, those capitals and their sources are linked to different development systems, based on capitalist, statist, participatory and traditional ideologies.

Sixty farmers in two villages compared six modes of transport and the capital use systems under which they were accessed. Thirty of them similarly compared compost and fertiliser.

Strong sustainability was highly relevant as crops grown with water retentive organic fertilisers consistently outperformed those fertilised inorganically. Wealthier farmers could purchase fertiliser, implying the capitalist paradigm, but most joined participatory groups through which they obtained subsidised fertiliser on credit: a mixture of participatory and state systems. Ability to use compost, however, was controlled by vehicle access. The best carriage system involved donkey carts, which were larger and could be used almost all day, and bicycles, owned by most farmers. Vehicle access was easiest when richer individuals owned large vehicles and hired or lent them to peers, combining capitalist and traditional systems. A second strategy was useful when no one in the community had enough money to purchase a vehicle. This involved participatory group ownership of large vehicles, supplemented by ownership of small vehicles that could be used at the owners' convenience.

Different systems gave access to fertiliser and transport because different contexts surrounded each. Not everyone can afford to buy fertiliser, which is a subtractable good; whereas vehicles, which are less subtractable, are increasingly available to richer individuals. The unique contribution of this thesis is to demonstrate that different access mechanisms to sustainable livelihood activities are appropriate in various contexts. However, the most successful always involve a mixture of modes or systems.

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Acronyms

AEO - Area Extension officer

AGRA - Alliance for a Green Revolution in Africa

ATNESA - Animal Traction Network for East and Southern Africa

CLI - Crop Livestock Integration

GR - Green Revolution

IMT -Intermediate Transport

ISFM - Integrated Soil Fertility Management

LEISA - Low External Input Sustainable Agriculture

MOFA - Ministry of Agriculture

OIC - Opportunity Industrialization Centre

OM - Organic Matter

SFM - Soil Fertility Management

SOC - Soil Organic Carbon

SOM - Soil Organic Matter

SAP - Structural Adjustment Programmes

SARI - Savanna Agricultural Research Institute

SSA - Sub Saharan Africa

T+V - Training and Visit

UDS - University for Development Studies

Glossary

Anfani - benefit

Benzirigu (pl. benzirra) - means of transport (lit.- 'something to carry')

Bora- need/want/like

Dagbon - The tribal area the study takes place in

Dagomba - The adjective for the people that live here

Dagbani - The language

Kalabule - system of corruption

Kayayoo - Head porter

Kparaba - Work party

Kulum - fertiliser

Kulum tam - compost

*Nahang*a - foster nephew

Piringa - foster niece

Puuni - bush farm (lit. - 'farm')

Sanbanni - compound farm (lit. - 'outside')

Tahali - headpan

Tampooli -household rubbish

Trocko - handcart or hand trick

Yelimugirisili - problem

A kraal in Zaazi

Chapter One

Introduction

1.1 Soil Fertility Management in West Africa

The quality of West African soil has always been of paramount importance for those who live there. Relationships between agriculturalists, herders, weather, geology and ecology coalesce around agriculture, still a central pillar in the lives and economies of most rural West Africans living both in the forest zone and the savanna. The issue of soil fertility in particular is central. This study examines how Northern Ghanaian savanna smallholders' assets and capital endowments affect their ability to fertilise their maize effectively. It uses the problem of how they transport organic amendments to their fields as a mechanism to explore the systems they use to access the capital and resources they need for sustainable Soil Fertility Management (SFM).

Study of soil issues draws on many disciplines. Geologically old soils like the Acrisols, Oxisols and Ultisols of West Africa are low in organic matter and nutrients (Irvine and Ahn 1970) and the smallholder farmers who consistently crop on them can rarely afford fertiliser (Bayorbor *et al.* 2006). The unpredictable monomodal savanna climate and increasing dryness in more Northerly regions of West Africa mean that soil water retention is of paramount concern (Sultan *et al.* 2005) so a wider focus on soil *quality* rather than just fertility is helpful. Many scales also inform the work. Geology, climate and economics can be regional concerns, but globalized food, fertiliser, fuel, labour and aid markets extend the relevance of the matter to the international scale.

Accordingly, SFM research is moving in an interscalar (Krogh 1997; Manlay *et al.* 2004) and interdisciplinary direction. The social and financial issues surrounding soil and the way it links to other livelihood themes and activities have been recognised (Shepherd and Soule 1998; Osbahr and Allan 2003; Tittonell *et al.* 2005). However, examination of the specific technical mechanisms through which these themes and activities interact is less common. The role of transport is acknowledged (McClintock and Diop 2005) and there is a body of literature examining the role of Intermediate Transport (IMT), the second main focus of this thesis (Malmberg-Calvo 1994; Sieber 1998; Starkey 2001). It is, however, harder to find detailed case studies and descriptions of the exact events and processes that link SFM and particularly IMT to political and economic theories of land, labour and capital. This may be because the technical nature of many activities means they are framed as merely practical concerns, thus ignoring their role as cogs in a bigger picture. A critical example is how the theme of transport is mostly addressed through the grey literature (e.g. Riverson and Carapetis 1991; Malmberg-Calvo 1998; Starkey *et al.* 2002). Despite having value in the depth and detail of case studies it presents, such grey literature sometimes falls short of addressing the larger paradigmatic debate that technical development problems are part of. This study aims to bridge that scale gap, relating very detailed data from an in-depth study to elements of globally relevant capital ownership systems and development paradigms.

The livelihoods approach is a relevant framework for this interdisciplinary study because it recognises the links between disparate strands of smallholder activity. The model (Scoones 1998) emphasises how the ability to source at least five types of capital (natural, financial, physical, social and human) (Carney 1998) affects the nature and quality of people's livelihoods. This study will use that conceptual framework to consider how smallholders' capital endowments and the context specific mechanisms of access to them affect their ability to adopt different soil fertility and livelihood strategies. Authors like Scoones and Toulmin (1995) have taken such an interdisciplinary approach, relating how smallholders' historical, social, political, physical and spatial contexts interact to define the activities, including SFM, they pursue to make a living. An important aspect of the study will be consideration of how farmers make substitutions between these different types of capital to carry out the SFM activities they need to within their overall livelihood strategies. In this it examines the issue of SFM, hitherto examined in more technical sense, in relation to and connection with the other activities people pursue in their everyday lives.

As the potentially contentious term 'capital' is central to this study it must be defined here. Capital is a pivotal concern in many different ideologies and disciplines and has different associations and connotations in all of them. Most obviously the Marxist use of the word represents a means of production. In this study, 'capital' is almost always used to mean the assets individuals use in production and reproduction, as defined within the livelihoods framework. Chapter two will explore the criticism that this forces an economic conceptualisation of the idea, and so the words 'assets' and 'resources' can be used, as they occasionally are in this work, although this is not entirely successful in displacing the concept from an essentially capitalist framework. When the word 'capital' is used alone here it encompasses all the types listed in the livelihoods framework, and the idea that actors own resources or have access to them. When a specific type of capital is implied this will be indicated.

While this study recognises the importance of capital as understood by the livelihoods model, it is recognised that this approach, and the concept of social capital in particular, has been criticised for not being political enough (Fine 1999). In particular the livelihoods model does not refer very explicitly to historically relevant political processes, concepts and debates (O'Laughlin 2002). This thesis takes up that challenge. The traditional economy and modes of production are two central examples of such issues that it addresses, and the main way it extends the livelihoods model into the political sphere is by linking it to four systems of capital ownership and associated development ideologies. Expounded upon further in Chapter two, these can be briefly summarised here as adhering to capitalist, statist and participatory ideologies; a fourth describes a system that could be called 'traditional'.

As smallholders engage with capitalism and commoditisation and populations move and grow, the question of how capitals are - and should be - sourced and allocated between various livelihood activities becomes increasingly pertinent. With agriculture remaining a major component of people's diversified livelihoods, decisions about how capital is allocated within SFM are also critical. SFM is thus contentious in Sub Saharan Africa (SSA) – as it was in the Asian Green Revolution (GR) from the 1960s onwards (Cleaver 1972). As well as the issues of equity that concerned writers then, environmental concern over degradation, sustainability and the finite nature of resources are now much closer to the surface and are seen to conflict with and correspond to different degrees with people-centred issues (Shiva 1991; Baker and Jewitt 2007). In addition, actors are increasingly positioned between traditional paradigmatic boundaries. As an example, proponents of fertiliser subsidy and agricultural commercialisation have traditionally been opposed, but the Alliance for a Green Revolution in Africa (AGRA) has recognised the value of both. Similarly, agroecologists previously advocated using only organic fertilisers, whereas nowadays they acknowledge that some inorganic fertilisers can be beneficially incorporated into 'sustainable agriculture' (Pretty 1995; Conway 1997), the very definition of which is disputed. Such crossing of traditional boundaries and the melding of traditionally distinct paradigms and schools leads to conflict and is a recurring theme in this thesis.

To some extent the lack of detailed analysis of the link between SFM and livelihoods in the literature is because there is still a disciplinary divide, not only in conceptual but also in methodological terms. It has hitherto been difficult for most authors to combine the 'hard' and 'soft' science methodologies, so styles of investigations have not entirely overlapped.

The study of agricultural systems in Northern Ghana began with the qualitative, historical approach of early 20th century anthropologists. Although the focus of Rattray and his colonial contemporaries was on the political institutions that they had a vested interest in understanding, later workers like Goody were obliged to consider the natural environment as it played a central role in the economy of many groups. Indeed, Ady, part of Fortes' 1947 survey in nearby Ashanti, commented on the ecological, economic and sociological components of that work that 'the fields of study cannot be separately defined'. She proposed that unified methods were appropriate, although she still fell short of framing the site as a holistic system.

Notwithstanding this, the disciplines continued to diverge: quantitative agricultural studies such as Nye and Greenland's seminal work on soil carbon (1960) were separate from the more descriptive regional geographies produced, for example, by Irvine and Ahn (1970), Morgan and Pugh (1969), Morgan and Munton (1971), Stamp and Morgan (1972) and Kowal and Kassam (1978). Disciplinary distinctions meant these books tended to describe the separate elements of the system under headings such as 'soil' 'transport' and 'agriculture', implicitly but not specifically linking them. Alongside this, thinking was developing in separate fields like political economy (Bates 1981) and labour studies (Swindell 1985) whilst the quantitative approach of work on natural resources focused on the technological solutions to 'ecological constraints' (Stoorvogel and Smaling 1990). Only Farming Systems Research came close to interdisciplinarity: as an example, Upton (1973) considered how farmers manage economic and social as well as agroecological risk in farm systems. In the 1980s the seeds of agroecology and participation theories were sown with books like Richards' (1985) 'Indigenous Agricultural Revolution' on farmer innovations. Geographers like Michael Mortimore (1998), Kathy Baker (2000), Bill Adams (1997) and Frances Harris (2005) recognised social and institutional as well as biophysical reasons for some of the prevailing patterns in agroecosystems , heralding a shift to integrated empirical methods. Simon Batterbury (2001) introduces politics and combines it with physical soil assessments in his political ecology focus on soil erosion in Niger. Similarly Osbahr and Allen (2003) incorporate cultural elements as they compare farmer ethnopedologies to the results of soil tests. Work in related disciplines like SFM (Bationo 2009) is starting to pick up on this, engendering some methodological and conceptual integration here too. Scale effects as well as methodological limitations are a reason for the hitherto narrow focus of some of the more discipline specific literature: it is not always relevant or necessary to examine the chemistry of an individual's field in relation to international development politics. Institutional and space restrictions conceivably also limit the scope of research - such a large interdisciplinary task can be more easily carried out in the context of a personally motivated work like a thesis than under the auspices of a discipline-specific organisation. This study is therefore able to focus very specifically on one aspect of SFM at a very small spatial and functional scale, but positions it within a globally relevant discussion about the role of different paradigms. In the process of explicitly diving into that interdisciplinary territory it confronts many of the methodological incongruities and paradoxes inherent in attempting to bridge disciplines.

1.2 The study context - the Dagomba farm household system

The study is located in a peri-urban district of the tribal area of Dagbon, Northern Ghana. Smallholders here have developed systems to reconcile the agroecological and socioeconomic constraints under which they work, systems which change with the surrounding conditions.

Close to the regional capital city of Tamale, some have responded to the land pressure brought about by its expansion by migrating to work in its service and industry sectors. Those who remain on the increasingly scarce farmland, however, have been forced to diversify and intensify to make ends meet as rising populations mean they can no longer use shifting cultivation to manage soil fertility as their forefathers did. Although some concentrate on market cash crops like rice, groundnuts and vegetables, most have some involvement with the maize that has replaced millet and yam as the staple. Male heads of the patrilineal household are responsible for growing the maize that feeds its members, usually on compound farms close to the village where the presence of humans and animals makes the land more fertile. Many own livestock, an invaluable source of income and food. Especially relevant to this study, livestock also provide traction and the manure that forms a major component of farmers' SFM strategy in a peri-urban environment.

1.3 Study problem and aims

The motivation for this work stems from conversations with such smallholders and is a response to the needs they identify. They describe a context where agroecological and capital constraints prevent them from practising SFM as effectively as they would like. The poor soils and unpredictable rainfall of the West African Savanna, combined with their inability to purchase sufficient fertilisers, define a situation where the use of organic matter is extremely advantageous.[1] Yet their ability to use it is restricted as they cannot afford the vehicles necessary to carry it to the fields (Bellwood-Howard 2009). Transportation is one of several limiting factors inhibiting the use of organic fertilisers and indeed fertilisers in general and acts as one of many problematics through which capital constraints can be examined. However, transport issues affect not only agriculture but almost every other sphere of smallholder life. The specific mechanisms through which transport relates to SFM can therefore be extrapolated to almost any other situation.

The study problem clearly illustrates the interplay of biophysical, agroecological and socioeconomic factors and raises issues of sustainability - the importance of soil organic matter implies a strong sustainability standpoint at odds with the capital substitutability inherent to the livelihoods model (Ekins *et al.* 2003; Neumayer 2003). Agroecology dictates the appropriate solution but the type and source of capital available constrains farmers' ability to implement it.

Due to the participant-led motivation for the project, its objectives are conceived thematically. These objectives are framed in terms of the capitals required to implement the strategies smallholders may choose between in two spheres - firstly between different SFM techniques and secondly between different types of vehicle for carrying organic amendments to the fields. The overarching aim is to consider which elements of different systems of capital acquisition and use best facilitate effective SFM in the study area, and to relate those systems to the four different development ideologies mentioned earlier. Thus, the work addresses the gap between theory and practice identified by scholars in the field of development studies at the turn of the 21th century (Pieterse 2001; Schuurman 2008). This will ultimately lead to a consideration of which elements of those systems could best contribute to sustainable SFM and livelihoods for maize smallholders in the Ghanaian Guinea Savanna.

[1] A major focus of this thesis is the comparison of organic and inorganic fertiliser. Wherever the word 'fertiliser' is used without the prefix 'organic' it is referring to inorganic fertiliser.

The main research question arising from this is

How do Dagomba farmers' capital endowments act through transport provision and its interaction with Soil Fertility Management to affect their yields?

In this thesis it is divided into three research questions:

1. How can smallholder farmers best carry compost to their maize farms and what are the capital requirements of that strategy?

2. What are the comparative benefits and capital requirements of different SFM strategies; in particular of composts and inorganic fertilisers?

3. How do different capital use systems interact to facilitate effective SFM in Dagbon?

1.4 Organisation of the thesis

These questions organise the remainder of the thesis, as follows:

Chapter two explores different sources and types of capital and how they relate to four development ideologies, with a special focus on the contentious social capital.

Chapter three relates these concepts to an overview of shifts in paradigms and associated methodologies in the SFM literature and provides a brief outline of the status of SFM and IMT in the study area.

Chapter four describes the study site in more detail before evaluating the quantitative and qualitative methods that were used to test the suitability of these strategies for Dagomba farmers.

Chapter five begins the analysis of how appropriate different systems of capital use are in facilitating effective compost carriage in the study site. It deals with the results of surveys and interviews pertaining to the first research question of what is the best mode of transport for carrying organic amendments to the farm and which system of ownership best facilitates its use. These systems of capital use draw upon different development ideologies, which are related to the practical strategies farmers choose for their livelihood activities.

Chapter six presents the results of field trials, nutrient and water retention assays and interviews comparing organic and inorganic fertilisation techniques, positioning them within a wider SFM strategy. The implications of capital utilisation here are compared with those of Chapter five in terms of paradigmatic significance.

Chapter seven draws together the findings of Chapters five and six to address how farmers do, will and could facilitate effective SFM in Dagbon and which elements of different development paradigms and capital use systems best frame and describe the processes they use. It considers how feasible and sustainable these are in a global situation where new interactions are proliferating between traditionally separate institutions, activities, structures and disciplines.


Ploughing in Ypilgu

Chapter Two

Sources of capital required for different livelihood strategies

2.1 Chapter conceptual framework and structure

This thesis is about the liquidity of capitals at the village scale and how they affect farmers' ability to adopt and use various Soil Fertility Management (SFM) and related intermediate transport (IMT) techniques. The discussion will be framed by the concept of five different types of capital, which is embedded in the livelihoods approach (Carney 1998). This literature review chapter therefore opens by explaining that model, along with a brief treatment of the contentious concept of social capital. The main body of the chapter explores the different sources and types of capital available to Dagomba farmers. The possible sources are presented as the individual, the household, the community, the state and finally international organisations and NGOs. Combinations of these different sources are linked to four different production systems, each characterised by different ways of gaining access to the various capitals under discussion. Those four different systems are also underpinned by differing social institutions and linked to different paradigms of development. The choice of these systems emerged from a synthesis and consideration of the literature and the data collected in the field, illustrating the iterative and evidence-led nature of the research. They are not proposed as a universally applicable typology but have been constructed as the most appropriate way of explaining and theorising the data from this study. They are best described as, firstly, the individual acting within a capitalist market-oriented system; secondly, state provision; thirdly, the participatory group and lastly, the traditional community system of reciprocity and obligation. In a very general sense, these might be labelled as private sector, public sector, participatory and traditional systems. As the study examines how different assets/capitals allow farmers to adopt various livelihood strategies, the innovation adoption literature also provides a useful reference at points in the chapter. The chapter ends by noting the interaction of these different systems and paradigms in the low-capital study context and introducing the important ideas of subtractability and excludability.

This chapter's description of the four possible socioeconomic systems lays the foundation for Chapter three, which looks in more detail at which types and sources of capital and therefore production systems are required to adopt specific SFM and IMT strategies. A key theme throughout these two chapters is the importance of site, scale and context specificity as it is demonstrated that diverse combinations of capitals, sources, production systems and associated development paradigms are implicated in different situations.

2.1.1 Capital use systems

Before moving on to the explanation of the livelihoods framework and the different sources of the capital it describes, the four systems that underlie this study will be contextualised in more detail. Paradigm shifts in fields as diverse as politics, economics, environment, development and agricultural studies have been influenced by and informed the debate around these themes, and acknowledging them reinforces the interdisciplinary nature of this study.

Classical economics describes a free and unrestricted version of capitalism, where rational individuals act in a market (Hyden 1995; Sapsford 2008). The neoliberal approach of 1980s structural adjustment policies (SAPs) espoused this ideology, (Simon 1999; 2008b), considering pure market forces to be the most efficient way to run a society. In Ghana, SAPs were adopted by Rawlings' government in the 1980s and typical policies followed: fuel and fertiliser subsidies were removed and parastatal marketing boards reformed in an attempt to improve farmers' access to the presumed benefits of the international capitalist market economy.

But the state can intervene and direct the extent to which its citizens are incorporated into the market through protectionist tools such as import and export tariffs and subsidies. This type of post-war structural functionalism generally aimed to improve social equity whilst still strongly promoting economic growth (Mongula 1994). Ghana's first president, Nkrumah, like Tanzania's Nyerere, adopted a strong element of state involvement in what he called 'African socialism'. The extent to which this truly comprised 'socialism' is debated, as peasant farming remained widespread and many of Nkrumah's large scale industrialisation projects were funded by Western capital (Cox 1966; Rahman 2007). The role of the state was not as strong in this model as it was in the truly socialist countries, like those of the Eastern bloc, early post-colonial Angola, or revolutionary Ethiopia, where the state owned all the means of production. It was certainly not totally separated from private capital, and in this structure the two continue to antagonise as well as complement each other in their respective relationships with the people (Chambua 1995).

Both the pure market approach and that of structural functionalism are part of the modernisation paradigm that has its roots in the Enlightenment (Schuurman 1993; Willis 2005; Power 2008). Within that modernisation theme, the model of socialist state ownership of resources and industry is at one end of the spectrum and the neo-liberal, classical economic model of the individual acting rationally within the market is at the other (Hettne 1995; Simon 1999). Conceptually as well as in terms of scale, the model that emphasises the role of community action lies between them, and is expressed in the participatory development paradigm. Concerned with the formation and organisation of community-based participatory groups, participation links to the livelihoods approach in its focus upon human and social capital (Bebbington 2008). It emerged within development studies in the 1980s and is now a dominant paradigm in development practice. Willis (2005) identifies it as one of many 'bottom up' approaches to emerge from the 'development impasse' that Pieterse (2001) and Schuurman (2008) explain as resulting from disillusionment with the monolithic top-down modernisation paradigm. The focus on building institutions like participatory groups, both as autonomous organisations and as interlocutors between the state or market and the people, is one result of this impasse (Hyden 1995; Leperies 2008).

However the theme of community and social capital inherent in participation was not new: it builds on the 'principles of sharing and reciprocity' that Amoah (2009), among others, characterises as a traditional feature of African cultural heritage and a basis for development (Barrat-Brown 1997). This traditional interaction of the social and the economic existed long before Westerners described it with the term 'social capital', and such ideas of community and common interest formed part of the basis of Nkrumah's African socialism (Magesa 2009). There are multiple descriptions of systems of mutual assistance within kin, household and community groups. For example, Bovin and Manger (1990) describe how Fulani, Hawamza and Barabaig pastoralists adapt their social arrangements and mutual help systems in the face of environmental and political stress. But these systems are not only for emergency situations - the moral, religious and social interlinkages they represent also extend into the realm of everyday economic activity at multiple scales. Meagher (2010) shows how Southern Nigerian Igbos organise into groups based on their ethnicity for solidarity within their trading communities. In the North of the country, Hausa women engage in friendship groups but also rely heavily on individual gifts from male kin to fund their enterprises (Meagher 2001). Similarly, Arrhigi and Saul (1968) describe how the ownership of the means of production in African societies is often acquired through kinship and tribal rights and also how 'social cohesion is fostered through gift giving'. The interlinkages between economy and society thus act at the community as well as the individual and household scales. Hyden (1980) uses the term 'economy of affection' to describe these systems, and this mixture of terms from different disciplines (economics, anthropology) emphasises that (economic) relationships between kin are not always entirely altruistic. In a relevant illustration of that, Arhinful (1997) explains the social nestedness of the culturally complex funeral business that is so important in Ghana. Comparing people's willingness to invest in this industry with their behaviour towards their relatives' healthcare in the context of the then impending national health insurance scheme, he raises issues about the relative efficacy and role of kin and state service provision.

Of central importance to African rural productive systems, kinship provides access to farm labour, (Swindell 1985; Deegan 2009) as well as cash. As well as at this local scale, kin and ethnicity plays a role in the clientist relations that still often pertain in national and local chieftaincy contests and parliamentary politics. Emphasising the inextricability of culture and economy, 'post-traditionalist' authors like Nabudere (1997) and Graiouid (2007) have even reformulated traditionalism as a cultural movement at least in part resisting the modernisation development paradigm. Although there is speculation over how quickly these practices of traditional mutual cooperation are being eroded (Deegan 2009), they were still common enough at the study site for this traditional societal mode to emerge from the data as a fourth, African, economic paradigm.

The elucidation of these four ideologies is informed by the data. They are useful as an analytical framework to help identify which actors and ideas interact as people source the assets they use in their agricultural livelihoods. In reality these four systems co-exist in space and time, so farmers' activities defy rigid classification within such a typology, as 'post-development' commentators like Pieterse (2001) acknowledge. At the same time, there are still normative opinions about which represents the best means to achieve the developmental end: although post-development scholars continue to debate what that end is. This chapter will begin to reveal how the different paradigms interact, and such multiplicity is the main theme that will resurface repeatedly throughout the whole thesis. In the results chapters it will be revealed which elements of each system are appropriate to this particular context but the conclusion will return to framing those results within the overall theme of co-existence that is developed here.

Considering this simultaneity of development paradigms, the co-existence and interrelationship of capitals in the livelihoods model make it an ideal framework upon which to base the study.

2.2 Livelihoods and capitals

The concept of a sustainable livelihood developed in the 1980s from Sen's (1981) description of how famines were caused not by a dearth of food or money but by weak entitlements and poor access to resource bundles. Devereux (2001), however, criticises this approach as overemphasising economic aspects and paying insufficient attention to political and social factors. Participatory methodologies are often used in and associated with livelihoods studies, illustrating that networks and relationships as well as cash income are important to people's lives (Murray 2001). By 1997 the livelihoods approach had been formalised to distinguish between different types of resource (Bebbington 1999), initially described in a 1997 Department for International Development (DfID) white paper (p.18) as 'created', 'social', 'human' and 'natural'. Following Carney (1998) the capitals are now usually presented as social, natural, human, financial and physical (Ellis 1999), although Scoones (1998) points out that these are just five of many. He describes how people access these capitals through institutions in order to enable them to pursue their livelihood strategies. Scoones argues that the issue of access mechanisms is more important than the existence of the capitals themselves. This model is illustrated in figure 2.1

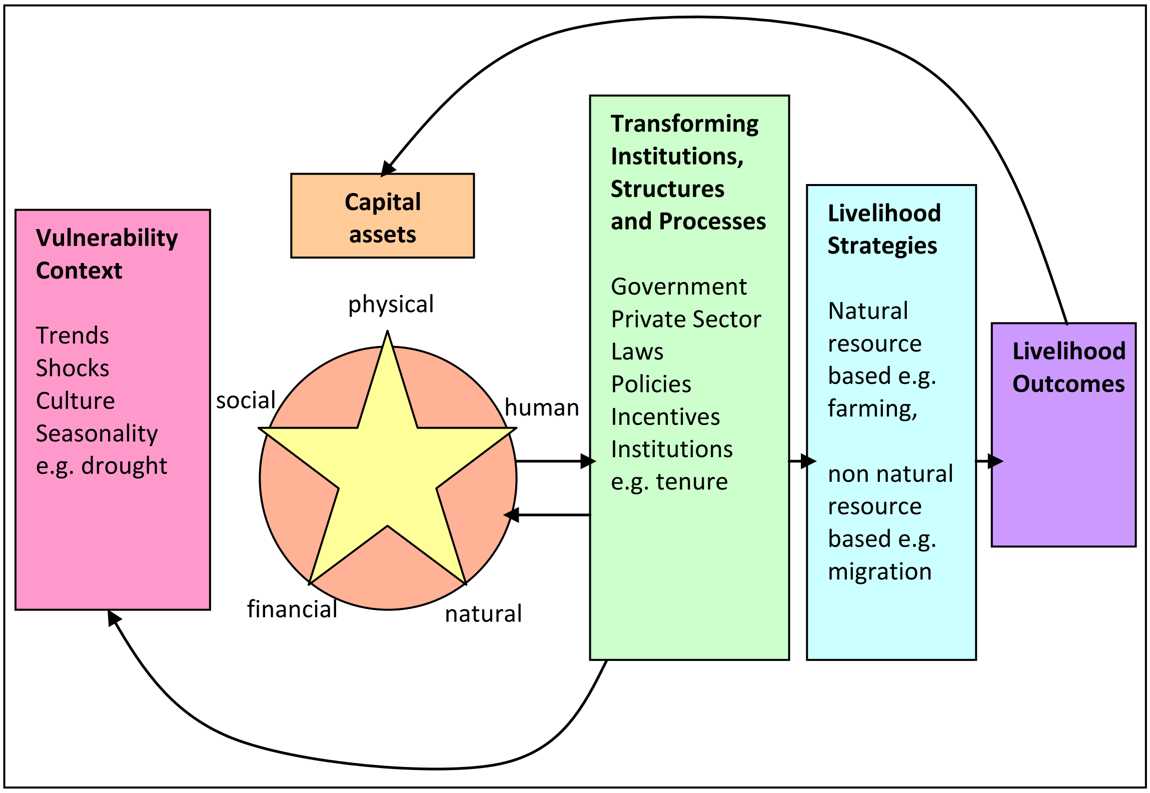

Figure 2.1 The Livelihoods Framework.
Adapted from Ashley and Carney (1999) and DFID (1997).

These capitals, their sources, and the mechanisms of access to them at the village scale are the focus of this study. The livelihoods model, like participatory approaches, emphasises the importance of social capital (Bebbington 2008). Social capital has been explicitly identified as a factor affecting agricultural livelihoods (Bebbington and Perreault 1999) often built through participatory methodologies (Uphoff 2001). This and section 2.3 will therefore assess the utility of the concepts of social capital, livelihoods and participation against critiques mainly addressing their apoliticism. Sections 2.6 - 2.10 will examine the sources and types of capital available to the semi-subsistence farmers participating in this study and the relationship of these ideas to debates over modes and paradigms of production.

The livelihoods approach has been criticised. Its non-sectoral and multi-scalar nature led Carney (1999), an advocate, to describe early fears that it is overambitious. However, for this study these characteristics are strengths rather than weaknesses; the interdisciplinarity of the approach makes it appropriate to apply to the relationship between transport and soil fertility. More significant here are the potentially political critiques that the model distracts from distributional issues related to the inequitable spread of capital between rich and poor (Carney 1999) and thereby absolves those responsible from responsibility. This may mean that the symptoms of structural inequalities are addressed whereas sustained positive change really requires much deeper reforms to tackle the causes. Related to this, the livelihoods model does not explicitly consider the source of the capitals, although the institutions governing access to them may be located within certain actors or their interrelationships. As capital emanates from different sources in different systems, the model does not therefore address the appropriateness of different production systems and development paradigms. Indeed, although it is mentioned by Scoones (1998), political capital is not commonly among those capitals detailed in livelihoods approaches (Rakodi 2002) as it is often ostensibly absorbed within social capital.

Marxist authors also consider the livelihoods model apolitical (Bryceson 1999c; O'Laughlin 2002), and, with reference to Southern Africa in particular, neglectful of class processes like proletarianisation and power relations that form the historical and political backdrop to the way in which people's livelihoods have developed. They argue that the model therefore struggles to identify the obstacles that inhibit positive changes. Critical authors from many schools of thought emphasise the relevance of politics to African development in the 20th century, at scales ranging from the international to village levels. Price (1984) ascribes the dismal state of the Ghanaian economy in the 1980s to internal political weaknesses rather than neo-colonialism: a close association between the government and certain sectors of society and thus a lack of economic autonomy. Nabudere (1997) is typical of authors who see colonial influences perpetuated in multilateral post-colonial development approaches, with Mosse (2001) applying the same critique to what he calls ‘development management’. Mercer *et al.* (2003) like Power (2000) relate this specifically to the 1997 DfID white paper embracing the livelihoods approach. These critiques re-emphasise the necessity of contextualising livelihood studies within a larger scale.

A related criticism is that describing social and human qualities as ‘capitals’ implies ownership, forcing them to be framed in economic terms (Fine 1999; Smith and Kulynych 2002). Yet Pretty (1999) described how natural and social capital need not necessarily be conceived of as a fixed stock but can be regenerated. Regarding human capital, labour may be owned, but new knowledge can be created. The livelihoods model therefore does not necessarily always have to conceptualise natural, human and social capitals as fixed assets in the same way as money and tools.

The interchangeability of the five capitals of the livelihoods model implies ‘weak sustainability’- the idea that in dearth of one capital, another can be used to replace it. An important critique of this idea comes from the ‘strong sustainability’ concept. This considers that there are some forms of natural capital, performing critical ecosystem functions, which cannot be replaced by others (Ekins *et al.* 2003). This challenges the liquidity of the capitals in the livelihoods approach. Weak sustainability allows the interpretation that rising incomes may counteract natural capital depletion, as in the wealthy half of a Kuznets curve, whereas strong sustainability holds that exhaustion of some forms of natural capital for financial profit cannot be reversed (Neumayer 2003). Permutations of this classification have been proposed - from ‘very weak’ to ’absurdly strong’. The latter precludes use of any form of natural capital, on the basis that once a capital is ‘finished’ it cannot be replaced and the effects of removing ecosystem elements are uncertain: it is not known whether a component, such as a keystone species, will comprise ‘critical’ and irreplaceable natural capital until it has been removed. There is a moral element to the classification of natural capital - Naess’ (1973) deep ecology recognises the intrinsic value of ecosystem functions, in contrast to the shallow ecology that classifies them on the basis of their utilitarian value. Actors' normative preferences for strong or weak sustainability determine which solution to environmental or developmental problems they consider 'should' be adopted. The livelihoods model, on the other hand, concerns itself with which capitals can be used to achieve those ends. The debate over sustainability will be crucial when moving from this chapter's examination of capital substitutability to the comparison of inorganic and organic fertiliser solutions themselves in Chapter three.

2.3 Social capital

Of the five capitals, social capital, a term first used by Bourdieu in 1986, has been the most contentious. Social capital has been conceptualised and described in many ways. One of the best known proponents, Coleman, (1988), describes it as operating by establishing reciprocity and trust, opening channels of information and reinforcing social norms and their associated sanctions. Coleman conceptualises social capital as being held not in one body or by an actor but in the relationship between them. Harris and de Renzio (1997) consider that this definition allows it to accrue to individuals, whereas that from Robert Putnam, a second key exponent, characterises it more as a property of communities (Putnam 1993). Bourdieu described how social capital was liquid and could be exchanged with the more tangible forms of capital (Bourdieu 1986). Woolcock (2002) and Evans and Syrett (2007)distinguish between bonding capital, held between similar actors, and bridging capital, occurring between dissimilar groups. They claim that the former is held more by rural, isolated groups and women and the latter in urban communities and by men. Linking capital is a third type in which less well endowed groups forge links with those having access to more assets. The common practice of substituting an individual's membership of groups as a proxy for 'social capital' therefore means that the importance of bonding capital can be overestimated. For example, such bonding social capital was only one type involved in the relationship between Ghanaian tomato producers and traders examined by Lyon (2000). This multiplicity of definitions led to Narayan and Pritchett's (1997) description of social capital as 'many things to many people' (p.2) and led Fine (1999) to call it 'catch-all and ambiguous' (p.10), and its essentially qualitative nature leads Evans and Syrett (2007) to suggest it is more helpfully 'interpreted' than measured. The recognition of 'historically formed social capital' (Pelling and High 2005) reminds us that it is a resource that has existed long before Western academics named it thus, hence its importance to development practitioners, who advocate harnessing it.

Like the criticism of the capitalisation of human characteristics in the livelihoods model, Fine and Green (2002) attacked the idea of social capital as 'economic colonisation of the social sciences'. However, most significantly, social capital is also condemned as an apolitical solution absolving the state and the international community from responsibility for a developmental role (Harriss 2002). Bebbington (2008) said that this is because the current conceptualisation has left behind Bourdieu's original definition which incorporated a political as well as an economic aspect. Harris and de Renzio (1997) cautioned that using Putnam's definition, which sees social capital as an inherent characteristic of some communities, could allow policy makers to 'pose civil society against the state' (p.934), in a supposedly dichotomous choice between two modes of governance. They rightly object that the relationship between civil society and government is more nuanced. The complex role of what is now called social capital in social functioning can be illustrated by how it has interlocuted with descriptions of state and community organizations in more longstanding debates relevant to the study area.

2.3.1 Social capital in historical context

The concept of community level social capital has special historical implications in the study of the socioeconomic relations of African village life. In the 1970s the debate around modes of production identified that so-called 'traditional' societies did not fit into the Marxian description of different 'modes of production' sequentially succeeding each other in a pathway from capitalism to socialism. They did not conform to the stereotypes of ' primitive communist', 'slave' 'feudal', 'Germanic' or 'capitalist' modes of production' (Klein 1985). The form of capital appropriated by a ruling class in such economies did not derive from surplus labour. This led some, in particular Suret-Canale (1964 cited in Gakou 1987), to position the African society model in the 'Asiatic' mode of production. Coquery-Vidrovitch (1975) derived a specific African mode of production in which a ruling class appropriated capital from long distance trade.

This theoretical debate about production at the state scale in the 20th century is less relevant to our empirical village scale analysis of reproduction in a 21st century community. However, the main point to link to it is that the social capital mechanisms integral to the functioning of village economic systems means they defy classification within Marx's framework. A second reason for this is that they comprise elements of *all* his 'modes of production'. Hyden (1980) described what he called the Tanzanian 'economy of affection' as 'pre-capitalist' and, in the 20th century, unique to Africa. Hyden's work illustrates the positioning of reality between theoretical paradigms that resurfaces repeatedly throughout this work. Another important point is that one characteristic of African communities is group labour at the household and community scale (Swindell 1985; Maghimbi 1994), often for reasons of timeliness. However, this is not entirely comparable to Marx's 'primitive communal' mode of production, because the benefits of communal labour are more usually enjoyed by each of a group of participating individuals rather than communally. This use of community labour is one of the reasons social, along with human, capital is often claimed to be the most abundant asset held in developing societies (Woolcock 2002; Morgan 1977; Fukuyama 2002). Indeed, Clark (1979) considers such exchange economies, not only in Africa, may be a result of shortage of financial capital. Time honoured traditions of reciprocity (Thomas and Worrall 2002; La Ferrara 2003) and kinship (Holy 1996; White 2000) that act at individual, household and lineage as well as community scales are the background to the modern idea of 'social capital'. These make it more difficult to distinguish between 'economy' and 'society' (Afonja 1981). Fine's (1999) criticism that the amorphous nature of the term 'social capital' means that it facilitates unjustified macro-interventions may be justified, but that very non-specificity also means that the term can describe something that is undoubtedly part of the socioeconomic functioning of the African village context. Bohannan (1955) describes the traditional exchange system of the Northern Nigerian Tiv, who used categories of goods that could be exchanged for one another, among which were wives and dependents. This interaction of kinship and marketing spheres and the exchange of financial with other capitals confirms that the livelihoods model, which does not necessarily valorise or elevate money above other forms of capital, is a useful tool with which to examine the socioeconomy of a Dagomba village.

2.3.2 Social capital and participation

Participatory ideologies also adopted social capital, often in approaches that simultaneously built or conserved natural capital (Scoones *et al.* 1994; Pretty and Smith 2004). Again, critics, for example those contributing to Cooke and Kothari's (2001b) collection describing participation as 'tyranny', identified that participation's devolution of the responsibility for development onto the community and individuals, grouped together under the name of 'civil society', echoes the 'apolitical' co-option of social capital by neo-liberalism articulated by Fine and Green (2002). Even originator Chambers (2001), alongside Pretty (1995), described how some forms of participation can be passive, by consultation only, or even disingenuous, and in these cases the most powerful actors amongst the participatory group, including the facilitator, benefit.

The critique that participation and social capital regard the community as homogenous, thereby ignoring intra-community power relations, is also politically relevant. Feminists consider that focusing on the household risks ignoring women's relative disempowerment within it (Nussbaum 2000). However, Sen (1987) tackled this issue with the concept of the individual's 'breakdown position'; their ability to bargain as an individual with other household members. Cleaver (2001) makes another politically relevant critique, describing how participatory methods ignore existing decision-making processes. But again this provides an opportunity to reflect on whether 'social capital' plays the same role in different production systems. Much of the analysis of data in this work will contrast the participatory system with the 'traditional' one of sharing and borrowing friends', neighbours' and kin's capital, and the decision-making processes of the two systems certainly interrelate and possibly conflict. Participatory groups act alongside the 'traditional' decision-making processes that prevail in villages such as the study communities. Meetings, group decisions and autocratic decisions by elders are characteristics of Dagomba village functioning. This process can successfully interact with or alongside participatory methods. On the other hand, if a participatory group makes decisions contrary to or without consultation with the traditional leaders, conflict may arise. This is a question of social capital - elders have social capital that places them at the top of a hierarchy, whereas a participatory group supposedly gives its members equal amounts of bonding social capital that enables them to make decisions. If the two types are able to co-exist, the traditional and participatory systems function concurrently. If not, one, most likely the newer participatory system, must give way.

Other critiques of participation are less relevant to this consideration of the sources of capital and capital ownership systems. For example, Mohan (2001) considers that emphasis is placed upon the facilitator. Participation may become an end in itself (Cooke 2001; Williams 2004) and over-romanticise the idea of being 'local' (Mohan and Stokke 2000) and groups may make decisions that individuals would not make alone (Cooke 2001). Yet rather than abandoning the concepts of participation and social capital, many advocate their repoliticisation, e.g. by framing participation as radical citizenship - an opportunity for research participants like farmers to choose and dictate the terms of projects in an alternative choice to capitalism (Cleaver 2001; Zuern 2003; Samers 2006).

Repoliticising social capital implies emphasising linking rather than bonding or bridging capital. Here communities would have the ability to 'reach up' to external organisations, including the state, that hold resources and power (Woolcock 2002; Pretty and Smith 2004; Evans and Syrett 2007). The community and state, however, are not diametrically opposed opposites (Goody 2007b). This again illustrates the thread running through the study: choices between different sources of capital are not necessarily dichotomous alternatives. On the contrary, Evans (1996) and Ostrom (1996) have lauded the relationship between state and civil society as synergistic. The bulk of the literature therefore now diverges from whether the concept of social capital is useful at all to how it can best be harnessed (Woolcock and Narayan 2000). As the literature has proliferated there has been less consensus on which types of capital are located in which 'communities of place and practice' (Pelling and High 2005 p.315) and indeed in which relationships between them. In reality, individual actors exist in a multiplicity of identities and have multiple ties of different natures within and between these. Different types of social capital existing within these relationships may be difficult to define or isolate. This study has found it most helpful to use theories of social capital as a classifying framework within which individual interpersonal links, rather than entire situations, may fit. This suggestion is admittedly open to the criticism of leaving social capital as a semi-defined concept (Fine 1999), but it is a realistic and practical application. Finally, despite the description of different types of social capital as part of a more practical deconstruction of the concept, there is still little explicit examination of the differences between how the capitals held by individuals and by communities would function in similar situations or indeed how they may work together. Pretty and Ward (2001) and Pelling and High (2005) called for work on the relationships between communities, individuals and social capital, and this study will address this need.

2.4 Sources of capital

Sections 2.2 and 2.3 focused on political critiques of the livelihoods framework, social capital and participation. This forces a consideration of the sources of the assets that enable people to raise soil fertility and also of the institutions that constrain access to those assets. This study associates those institutions with four different development ideologies and systems. It considers how well each can provide farmers with the capital they need in order to be able to carry their compost and fertilise their farms effectively. Each system acts at a range of scales, but can be associated with one in particular. If the analysis is to consider all these without valorising any particular one, it must take care to extend rather than merely shift its scale. Livelihood capitals are often examined at local scale but enlarging the scale means all the sources, including the state and international donors, can be considered. Losing the specificity of the focus at the village level risks considering the community as homogenous, one of the failings of the participatory approach identified in Cooke and Kothari’s collection. This study will follow authors like Sen (1987; 1990) and Nussbaum (2000; 2003) who avoid making that mistake by breaking up the ‘black box’ of the ‘community’ and ‘civil society’ into individuals, community and household, and simultaneously it will consider the role of the state. As bodies external to the community, NGOs fall outside ‘civil society’ in this story and are in a category of their own.

For the purposes of the study, these different sources of capital are linked with the four different systems of production and development. The provision of capital by the state implies the type of solution proposed by the socialist and developmental governments that emerged after independence in many African countries, including Ghana, but also by their colonial predecessors. The capitalist system of market exchange is related to the transfer of capital between individual owners in an economy based on the private sector. The participatory paradigm is associated with capital mobilised by a formally self-organised group. Although participation may occur at other scales elsewhere, in this study such groups drew members from the entire community and thus here it is associated with that scale. In addition, some of the sharing, borrowing and gift-giving processes that operate within communities do not correspond to the capitalist, socialist or participatory systems of economic organisation. Such practices, although also linked to social capital, are termed the 'traditional' system in this study and distinguished from 'participation', a term which in this work is used to describe formal organisation into a society or group. In the 'traditional' system farmers borrow and beg from, share with and help each other on the basis of ties of kinship, neighbourliness, friendship, reciprocity, morality and obligation (Bloch 1973). This fourth, 'traditional' mode of organisation is defined by the form rather than the scale of capital transfer: the 'traditional' exchanges this study examines take place within and between households, communities and kin groups (Guyer 1981).

As different development paradigms have overlapped and waxed and waned in influence, authors have taken normative stances over the provenance of the capital required for development and the relative desirability of those different paradigms. Koning and Smaling (2005) are of the opinion that under SAPs reformed state institutions rather than NGOs or 'civil society' should be the driving force of development, playing a special role in price adjustment. Meanwhile, some World Bank authors, for example Malmberg-Calvo (1998), consider 'cost sharing', where the community contributes some of the cost, to be the only efficient option at the community scale. Gary (1996), however, hints at the reality of the situation in describing Government appropriation of funds targeted to NGOs. In keeping with this, what the following analysis demonstrates most significantly is that, despite the normative approaches of scholars and practitioners, more than one scale of organisation, source and type of capital is used in almost all situations or solutions (Hart 1975; Berry 1989; Ostrom 1996; Ellis 1998; La Ferrara 2003), usually because decision makers have adopted a range of strategies for reasons of efficiency and practicality rather than for reasons of ideology (Mpedi 2008). As an example, although proponents of participation advocate the use of social capital from the community on ground of empowerment, participatory methods have sometimes been used for practical reasons: they may be cheaper, quicker or use groups structures that already exist in the community.

So ideology is not always the key motivating factor in constructing the scale of social functioning. Another factor is that neither the rigid distinction between the ‘individual’, ‘household’ ‘community’ and ‘state’ scales nor the attempt to link each of these to a production paradigm is entirely representative of what happens in real life. It could also be argued that several possible units of analysis have been excluded: scholars of kinship, for example, have discussed and disputed its comparative significance to other systems of social organisation such as territory as well as the relative importance of different units of kin such as lineage, clan, extended and nuclear family (Holy 1996). Such fine distinctions are not the focus of this study - what it is concerned with is how relatively important the systems of market exchange, traditional sharing, participatory group formation and state support are in providing the resources farmers need to sustain their agricultural production. The distinction between the ‘individual’, ‘household’, ‘community’ and ‘state’ has been made because at some scale a boundary must be drawn between different sources of capital, and the ones most relevant to the study communities have been chosen based on field data. Although lineage, for example, is indeed important in Dagbon, it featured less prominently in respondents’ evidence than the individual, household and community scales. In any event, the major point is that the study is not attempting to find one capital source that is more important than all others but to explore how they interact in the field. In the same way that different modes of production articulate with each other (Dupré and Rey 1973; Clarence-Smith 1985; Freund 1985), examples of smallholders using elements from a range of systems in their livelihood strategies, usually for practical reasons, recur throughout this study. The aim is to observe which types, sources and systems of exchange of capital are most evident and which combinations of these have most potential for future use.

2.5 Resource access, excludability and subtractability

Thus far, the idea has been introduced that smallholder livelihood strategies may be analysed in terms of the types of capital they require, the scales at which these are used and the systems of access to resources this implies. These features form the basis of a classification system or typology of development systems and paradigms. Relating capital sources to overarching paradigms in this way means the study takes the livelihoods model out of the apolitical space some criticise it as occupying. As well as politics, a study examining 'capital' must draw upon economic theory. Reference to systems of access to resources draws direct parallels with the body of literature on rights of access to resources. This study draws on one idea in particular from that body of work - the typology of goods and services clearly elucidated by Ostrom and Ostrom (1977). This classifies goods and services into four types on the basis of their excludability - the ease with which people can be excluded from using them - and their subtractability - the extent to which one individual's use of a good makes it unavailable to others (Blaikie *et al.* 1987). Table 2.1 depicts the four broad categories within this typology as Polski and Ostrom (2009) describe them.

	Low excludability	**High excludability**
Low subtractability	Public good e.g. air	Toll /club/partially public good e.g. hire vehicle
High subtractability	Common good e.g. grazing land	Private good e.g. fertiliser

Table 2.1 Resource subtractability and excludability.
Adapted from Polski and Ostrom (2009).

This system of classification is very useful for examining the specific livelihood strategies considered in this study because subtractability and excludability explain why different paradigms and systems of capital use may be more or less appropriate in various situations. The results illustrate that the excludability of a resource is particularly affected by how it is owned and is also affected by the source of the capital it requires. Subtractability, however, defines how well the resource lends itself to being shared amongst individuals and thus has implications for possible modes of ownership and, coming full circle, for its excludability.

Ideas about different resource use regimes are therefore directly relevant to this study, but the work limits what it takes from the resource rights and regimes academic framework to the concepts of subtractability and excludability. It should, however, be noted from the outset that a major resonance between this thesis and the work on resource rights is with the latter's later realisation that property regimes are not necessarily exclusive typologies - elements from a scale of different systems co-exist and interact (Hanna *et al.* 1995).

Linked to this, a methodological issue that compounds the impossibility of making sharp distinctions between types, sources and modes of capital production is that it is very difficult to determine definitively the source of some forms of capital or indeed to define which type of capital it is. Such definitional problems make it even more difficult to describe the capitals implicated in development solutions. This is why the extended scale is important; examining the individual without ignoring the state recognises the interactions between different scales and ensures that an analysis relevant to the individual will retain awareness of their political surrounds (Bationo *et al.* 1998b). The analysis will begin at the smallest scale, considering what types of capital the individual may hold and how these may interrelate.

2.6 Individuals' capital

It is clear that the capital held or accumulated by the individual is essential in determining which livelihood strategies they can follow, and this section will consider the relative equity of its direct exchange in capitalist and traditional systems. The section includes examples of specific contexts where different exchange systems are differentially appropriate. It concludes by illustrating how an individual's social capital can also play a more indirect role, as an access mechanism to other forms of capital.

2.6.1 Direct exchange of individual capital

Direct exchange of capitals can be conceptualised as a market in which assets are fungible and liquid. Capital is not only exchanged between people - one individual may also substitute their own assets to perform given functions. In choosing SFM strategies farmers exchange different types of capital to enhance soil productivity. In direct exchanges the scarcest capital is limiting and this is probably why analysts emphasise the centrality of financial capital in rural Sub-Saharan Africa (SSA) (Dorward *et al.* 2004). Financial capital is closely linked and easily exchanged with physical capital, hence why early versions of the livelihoods model refer to 'created' capital (Scoones 1998). In the context of SFM and transport at the individual scale, physical capital includes fertiliser, donkeys and bicycles, as well as the less obvious tools, headpans and shoes, all of which exchange most easily with financial capital. Additionally, at the very small scale individuals could be considered to own infrastructure, including paths. Land, as a means of production, is physical as well as natural capital. The excludability of such individually owned goods means that they are amenable to being used within a capitalist system of private ownership and sometimes hire. Cash is not always necessarily implicated: the existence of exchange markets and the importance of reciprocity in this setting should be acknowledged from the outset. This leads to the recognition that individuals also access capital through informal and traditional institutions, where financial and social capitals interact.

In Dagbon, patrilineal inheritance means individuals crop on sites held under customary law and may sometimes exchange or share them with kin. An another example is provided by Fernando and Starkey (2004), who document sharing and borrowing as well as hiring donkeys in Kenya, Botswana and Ethiopia. Borrowing represents exchanges of reciprocity, rather than cash, and is integral to traditional African socioeconomic systems, confirming that individual capital ownership is a key element of both traditional and capitalist modes of production. Capitalism relies on the appropriation of surplus by certain individuals (capitalists), usually in the form of financial or physical capital. The 'traditional' mode of production that exists in the study villages relies on such individuals' ownership of capital so that their kin and neighbours can gain access to it through social capital, with the result that under this system it becomes slightly less excludable. Diffuse reciprocity and expectation of repayment either in similar or different forms of capital are part of these arrangements. As such, the traditional system is a less direct form of exchange system where repayment can be in social capital and obligation rather than tangible goods (Hart 1975). The extent to which capitalism and traditional systems interact and differ is disputed - although both require an element of individual ownership, the 'post-development' view of Escobar (1995) and post-traditionalists like Nabudere (1997) is that traditional societies often have good reasons to reject modernism. On the other hand, if systems of informal exchange work towards capital accumulation they can be seen as facilitating modernity as development, in the way that capitalism does. However, the ultimate difference is that the traditional mode entwines economic with social capital and through this reinforces the association between the capitalist end of profit accumulation and the networks of kin and friendship where it is not the exclusive goal.

Neoliberal authors consider that market competition is the most cost effective way of meeting development needs. For example, Hesse and Runge-Metzger (1999) opine that policy or NGO support should steer towards establishing a traction-hiring market in Northern Ghana, seeing incorporation into such a market as more efficient than individual ownership. They caution against credit schemes unless they facilitate development of the hire market.

The World Bank view on means of rural transport is that motor vehicles in particular are most efficiently owned and provided by individuals (Ellis and Hines 1998; Malmberg-Calvo 1998). Using the example of production of traction tools such as ploughs and harrows for sale to private owners, the pragmatic and somewhat fatalist view of Havard *et al.* (1999 p.299) is that 'it is on (artisans) that we must place hope in a liberalized economy' and similarly Bobobee (1999) implicates private enterprise in the development of plough technology. These as well as other authors from the Animal Traction Network of East and Southern Africa (ATNESA) adopt the argument that privatisation is efficient and pragmatic when state provision is comparatively poor, as it has often been in Africa. Such privatisation relies on the accumulation of individual capital both by those who own the means of production and those who wish to hire it.

2.6.2 Capital and communication in innovation adoption

However, although potentially efficient, the use of individual capital is often inequitable. In the agricultural context this is well illustrated through the critique of Rogers' 1962 communication diffusion model of innovation adoption (Rogers 1983) and the Training and Visit (T+V) extension method it gave rise to. This model emphasised the role of information and communication in facilitating farmers' adoption of innovations they could use in their livelihood strategies. Originally stemming from a rural sociology perspective, Rogers' model has interdisciplinary relevance and has notably been applied in a marketing context. Rogers divided the factors affecting technology adoption into the characteristics of the adopter, with emphasis on the psychosocial factors affecting 'communication', and the characteristics of the innovation - its complexity, testability, observability and the key element of whether it was compatible with the objectives of the adopter and their culture. He described the spread of innovation from the 'change agent' through a community, characterising adopters at five different stages of the process as illustrated in figure 2.2.

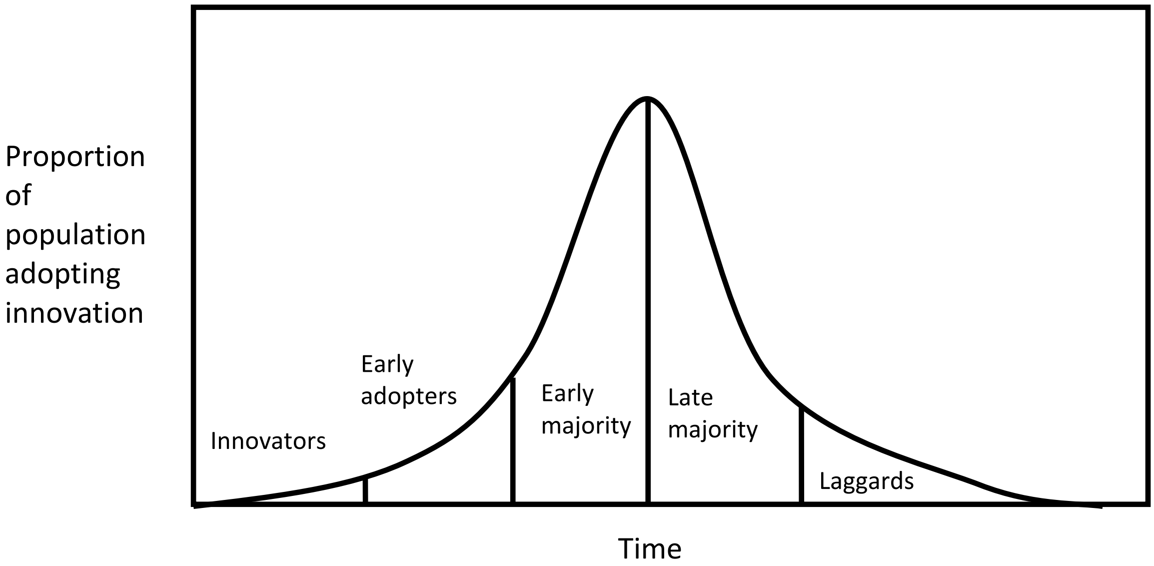

Figure 2.2 Categories of innovativeness.
Adapted from Rogers (1983).

The characteristics Rogers identified have been shown empirically to affect adoption (e.g. Abd-Ella *et al.* 1981; Ervin and Ervin 1982a; Okoye 1998a; Matata *et al.* 2008; Rezvanfar *et al.* 2009). The main critique of this approach was that in its emphasis on communication it failed to acknowledge the capital constraints restricting poorer farmers' innovation and adoption, allowing those who already had more individual capital to profit as they did in the open market. Rogers' model does not explicitly promote market capitalism: it is more the positioning of individuals' characteristics within a psychosocial framework (Isham 2002) that later political authors such as Goss (1979) objected to. When such a model is implemented practically, the *laissez faire* attitude involved means the rich, able to afford such risks of adoption as accepting credit (Harriss 1987; Harrison 1994), benefit first from new technologies and innovation (Gray 2005). As the owners of such physical capital as tractors and draft oxen they can guarantee the timeliness of their own farm practice and benefit from hiring their tools out to others in a market. Indeed in the later rural sociology studies personal 'income' and 'wealth' were consistently correlated with innovation uptake (Opare 1977; Rezvanfar *et al.* 2009). However there was little critical comment on this within that body of literature; such accounts rarely addressed causality or the institutional, macroeconomic or political causes of 'wealth' and so did not challenge the reproduction of economic stratification. When such a critique was advanced, the proponents of T+V proposed that the innovations adopted by the richest farmers would 'trickle down' to the 'laggards'. Use of this pejorative term illustrates the model's normative modernist presumption that it is desirable for all to adopt a given technology. Daniel Benor's (1977) version of the T+V system suggested, like Adams *et al*. (1982), that extension should tackle the 'laggards'' human capital development, whilst the richest individuals continued to accumulate physical and financial capital.

In contrast to the accumulation of physical capital, a more universally accessible market is the labour market, hence the reason those with access to few other capitals may often become providers of wage labour rather than adopting low external input methods. In the Asian Green Revolution (GR), where land was more of a constraint than in SSA, some became landless and some unemployed and many of the poor worked on the farms of richer capitalist farmers (Cleaver 1972). Baker and Jewitt (2007) found that the long term effects were more measured - 35 years later the standard of living of many was higher although they were still relatively poor in comparison to their former employers. The GR, with its emphasis on high technology seed and chemical packages that were adopted by wealthier farmers first, was a locus for much critique of T+V. The GR did not succeed in the same way in SSA as it did in East Asia. This was attributed to a lack of irrigation infrastructure (IITA 1992), inappropriate pricing policies and poor infrastructural and institutional development (Binswanger and Pingali 1988). Added to this were the inherently low soil fertility, variability in agroecosystems and poor fertilizer supply and subsidy policies identified by Bationo *et al.* (2004) as explanations for generally low African productivity. The Alliance for a Green Revolution in Africa (AGRA), established in 2006, is one institution that pushes for recognition and amelioration of the social and economic constraints upon adoption of agrochemicals and improved seeds. In recognition of the structural critique of Rogers' model, AGRA proposes that the individualistic market capitalism that underpins it should now be combined with an element of state support and civil society collaboration. This idea of a combination of market-led and state-supported sectors will be examined in more depth later in this chapter and in Chapter three. For now it should be noted that it remains to be seen whether incorporation into a market based on High Yielding Varieties and agrochemicals would have the same effect in Africa where land has hitherto generally been less scarce than in Asia, or whether such incorporation would continue to disadvantage the poorest individuals.

A further application of the diffusion model illustrates again the importance of context specificity: the recurrent theme of this work is that different models of capital organisation are relevant and useful to different situations. After analysts such as Ladejinsky (1973) and Harris (1972) rejected the capitalist themes of the GR and diffusion models of adoption in the 1970s, there was a resurgence of diffusion research in the 1980s. The focus of agricultural innovation adoption literature, however, shifted to conservation innovations within agriculture, including composting (Ervin and Ervin 1982b; Napier *et al.* 1984; Ashby 1985; Clearfield and Osgood 1986; Heffernan and Green 1986; Nowak 1987; Kashmanian and Rynk 1998; Sidibe 2005). As conservation innovations were perceived as less financially profitable in the short term the concept of direct financial advantage to the adopter became less relevant compared to environmental advantages. Authors therefore felt it appropriate to return to a consideration of the effects of communication rather than capital (Pampel and Es 1977; Taylor and Miller 1978). Richer farmers generally did adopt conservation innovations, as they did those enhancing productivity, even though in this context there was less immediate return of their investment. Such context specificity is evident in the plethora of adoption studies in the journal 'Rural Sociology', which to the present day tend to use variants of the diffusion model (Okoye 1998a; Matata *et al.* 2008; Miller *et al.* 2008; Rezvanfar *et al.* 2009). Typically low correlations ($R^2<0.4$) between adoption and explanatory variables such as farm size and level of education (Okoye 1998b) show that not all of Rogers' factors apply to adoption of all livelihood innovations as communication and capital are differentially important to different individuals' processes, sites and scales. At the level of the farmers' field it is convenient to make decisions based on their individual resource capabilities. Markets based on individuals' capital endowments may therefore be an appropriate model in this context. Timeliness is particularly crucial in the agroecological context, as the results of this study will unequivocally emphasise, especially at the scale at which the individual farmer works. Personal individual capital is essential for timely production and this is one reason the capitalist paradigm inherent in Rogers' model is relevant to the smallholder context. Situation specificity and individual capital often override efficiency or moral arguments, with the result that many adoption studies seem to be apolitical. Mercer (2004), in an agroforestry study, does describe three models of state, individual, and participatory capital provision but does not veer in the direction of any one, saying that the process specificity of agro-forestry implicates a site-specific approach. The return to the diffusion model and its capitalist associations in the 1980s could be seen as part of the return to capitalistic liberal arguments that accompanied SAP. Alternatively, acceptance of the relevance of this paradigm to some situations could be part of the postmodern realisation that different elements of all paradigms were in fact relevant to different contexts. Like the criticism of social capital, 'post-development' approaches have been critiqued because they can create a climate in which the liberal market may flourish and exploit those who are incorporated into it (Schuurman 2008). This criticism cautions against losing sight of political concerns about equity when advocating context specific solutions.

2.6.3 Individual capital exchange in the traditional economy

However, as described, individual capital and the market in which it acts in need not be conceptualised in the same sense as '*the* Market' as it is perceived in neoliberal economies and developed countries. The traditional 'market' of exchanges based on kinship or expected indirect reciprocity may exist instead of or alongside formal markets, and that system may be less inequitable than the capitalist one just described. Rogers' model looks at full adoption of innovations and technologies and does not consider the possibility of social capital acting to facilitate access to them outside a capitalist framework of full ownership. The traditional economy, incorporating borrowing and sharing between individuals, facilitates poorer people's access to those innovations before they themselves fully adopt them, just as it allows peers to share other more subtractable non-material assets like labour. Maghimbi (1994) describes how reciprocal labour between households existed as part of the peasant mode of production in the Ancient Ugweno Nigerian state. Both Berry (1989) and Bryceson (1999b) describe the traditional organisation of African decision making and labour power in community and household units, and compare it to its 'individualisation' in more recent times. In the traditional economy the ability to exchange such liquid capitals as labour may be less likely to disadvantage the poorest, particularly when reciprocity is diffuse or delayed. The line between 'gifts, 'loans' and 'exchanges' may become blurred as elements of obligation are involved, for example in cultural requirements such as almsgiving, which invoke the 'moral economy'. The moral economy can cause people to perform actions because they are expected to or want to rather than in expectation of direct compensation (Bloch 1973).

The extra dimension of cultural meaning means exchanges may not always be as straightforward as they are in the liberal marketplace, and their subtractability and excludability may vary in different situations. Markets and the value of items exchanged in them are socially constructed (Bloch and Parry 1989; Geschiere 1997): cattle, for example, hold a special significance, which means they are not always simply exchanged for a fixed amount of money (Hutchinson 1997). Such informal exchanges may play a particularly crucial role between kin and when obligations to family members are invoked the excludability of a good is definitely compromised. Institutions such as friendship, kinship and obligation thus act to even out the inequity that is often a result of individual accumulation within the capitalist market. Fine (1999) considered the World Bank's use of this observation to justify the continued dominance of market approaches in developmental strategy unfair. There is an element of truth in both positions.

2.6.4 Individual capital as an access mechanism

The primary function of capital is not always direct exchange. Social capital in particular often acts as an institution through which to facilitate other exchanges, for example in the informal credit network and the mechanisms permitting and providing employment. In a SFM example in the study area, vegetable farmers on the road from Tamale to Bolgatanga pay sewage truck drivers to dump waste on their fields (Owusu-Bennoah and Visker 1994; Cofie *et al.* 2005). A combination of their individual cash and the bridging social capital between them and the truck drivers ultimately gives these farmers access to the physical capital which the local government uses to collect the sewage.

Within the household, interpersonal relationships govern access to labour. Labour, historically the limiting factor in African agriculture, especially when land was relatively unlimited across the continent, becomes especially critical at times of peak farming activity (Schlecht *et al.* 2006). Substitution of financial and social capital to hire or share it then becomes significant (Swindell 1985). For the individual in this situation, the trust and reciprocity aspects of social capital are most relevant, whether they be direct or diffuse, e.g. in membership of a work party (Bourdieu 1986). Awanyo (2001) gives a fascinating account of the conjugal politics of weeding the invasive *Chromolaena odorata* in the cocoa belt of Brong-Ahafo, Ghana. Women withhold labour in certain circumstances as a tool of power over their husbands, forcing them to call on the assistance of their maternal family in this matrilineal society. Access to labour indirectly affects which farm processes a farmer can adopt - and thus has an effect on natural capital. Some Ghanaian farmers burn rather than slash weeds if labour is unavailable (Quansah *et al.* 2001). When burning is practiced every year in annually cropped savanna farms, crop residue is not returned to the soil and soil organic matter declines more rapidly (Bationo and Mokwunye 1991). Similarly, access to knowledge and skills is determined not only by an individual's ability to develop these qualities through formal or informal training, but also by the same intrahousehold mechanisms governing access to the labour held by other household members. This can be seen as bridging social capital - although individuals may live in the same household, education or training may mean they belong to a different intellectual or vocational community. Secure tenure can be seen as a form of access to natural capital and thus the physical means of production (Katz 2000). If inherited, as usually the case in the study area, it could have derived from social capital, but if purchased it results from financial capital. Like access to human capital, the form of tenure a farmer holds can affect which SFM practices they adopt, albeit through a different, less direct mechanism. The conventional wisdom is that private freehold most effectively promotes long term investment in soil fertility (Quansah *et al.* 2001), but there is also a suggestion that usufruct may be equally valuable in promoting sustainable soil management (FAO 2001; Pretty *et al.* 2002; Wiggins *et al.* 2011). All these instances show that individuals use their personal social capital to gain access to other resources. Social capital itself can be purchased with financial capital. Hart (1975) describes how Northern Ghanaian entrepreneurs buy favour with their home communities by distributing cash when they return from money making ventures in the South. Such practice gives them access to the labour and support of peers in their home town.

So individuals' access to capitals affects the livelihood options available to them, whether through direct or diffuse exchange or indirectly as mechanisms of access to other capitals. Many do not have the capital to engage in such quasi-market solutions- and this undoubtedly disadvantages the poorest. For them, traditional practices like diffuse reciprocity and exchange of social capital play a greater role than the capitalist system of individual exchange of financial capital.

In the Dagomba village the household head or 'landlord', an individual, acts both within and on behalf of his household. It is extremely difficult to differentiate between these scales, most of which act within multiple economic systems. Nevertheless, the transfers that occur between the individuals within a household in order to facilitate its reproduction are now considered in a separate section.

2.7 Household capital

Use of the 'household' as a scale at which to examine production and reproduction has been contested (Guyer 1981). It is, however, an important unit of reproduction in Dagbon. It can be perceived as one cooperative unit working to reproduce itself, although livelihoods authors view the household as a collection of individuals, each with their own capital endowment. Exchange occurs between these individuals: the junior members contribute their labour to the landlord's field and in return he feeds them maize. However, this particular exchange is not part of a capitalist marketplace as there is no surplus; Dagomba landlords rarely accumulate personal capital from maize. The transaction exists within the traditional mode of production, where, as mentioned, it is more difficult to exclude others from use of even subtractable goods. This added factor of kinship makes the distinction between this labour exchange and those which *do* create surplus difficult. Seniority can be a form of individual social capital which commands respect and labour by obligation, so junior members of the household may be obliged to help their senior kin in their private cash crop farms, for example tomato or groundnut. This shows that much property in the household is *not* communal - livestock owners often claim ownership of the manure their particular animals produce and apply it to their own cash crops. However, inasmuch as each member of the household contributes towards its general wellbeing, these exchanges within the household must be perceived as part of the special kind of traditional market inordinately influenced by traditional ties of kinship, obligation, respect and moral expectation. A non-agricultural exchange provides a thought-provoking example of this traditional system of reproduction - the parents of a *piringa* 'give' her at around four years old to her paternal aunt's household, exchanging the girl's labour for her material care. Dagombas usually describe the rationale for and benefits of this transaction as 'strengthening ties between the two sides of the family' (Kuyini *et al.* 2009), notwithstanding that an exchange of the child's labour for her school and feeding fees does take place. This is an example of a traditional situation in which the cultural and social meaning of kinship and the economic benefits of capital exchange are inextricable.

The household scale is important within both traditional and capitalist systems. Many social ties of kinship and obligation act here, as well as it being a traditional unit of production and reproduction, so it is also a site at which the two systems interact. However, due to the modernisation focus upon capital accumulation, whether through capitalist or socialist means, the household did not feature largely in mainstream Western ideas of development. Even African socialism took the idea of 'togetherness', perceived as inherent to African culture, and translated it to 'unity' at the community and state scale (Hyden 1980). The consequent 'othering' of such components of the traditional system as the household is another focus of post-traditionalist authors (Appiah 1991). This school of analysis of the contrast and resistance of African 'traditional heritages' to 'modernity' has placed emphasis upon the cultural aspects of social organisation, including language (Graiouid 2007; Prah 2009). This body of work is useful, although it does not specifically examine the economic transactions between individuals that are under analysis in this study. It illustrates how economics and culture are inextricable within the traditional system and highlights how this diverges from the purely economic approach of state and market focused paradigms. In contrast to these discrete schools of thought, the results of this study tend towards an affirmation of traditionalism as one of many co-existing contemporary economic systems and the household as one of many co-existing units of re/production.

Differentiations of scale are critical to the examination of intrahousehold capital exchanges. Individual household members may act within the capitalist system and when they acquire capital, for example through the sale of farm produce or hiring animal traction services, the household may or may not benefit from their profit. If the individual is a landlord it is likely that their profit will be passed on to the rest of the household for which they provide. When the systems of borrowing and reciprocity that may occur within the household are applied to physical means of production - rather than non-tangible assets like labour, the traditional and capitalist systems overlap. Individual capital facilitates ownership of such means of production, but the traditional system provides a route for other members of the household or community to access them by borrowing.

It is true that traditional norms may constrain as well as facilitate livelihood activities. Karbo and Agyare (2002) describe how 'communal' systems of land ownership can act as a disincentive to investment in sustainable land management and land sale is often forbidden in the areas of Northern Ghana where its allocation is determined by chiefs or priests. However, the most useful lesson to draw is that the capitalist and traditional systems can co-exist effectively, for in order for an individual's household and kin to gain access to their capital they must first acquire it, and for many forms of capital this is often through the capitalist marketplace.

The access of the household to the capital of those within it affects the livelihood options available to them. If their combined capital is insufficient to provide the livelihood they want they need an input of capital from elsewhere to raise their asset level. An additional source of capital conceptualised in this instance is that found in the 'community'.

2.8 Community capital

It has been noted that social capital is a longstanding feature of community functioning, contributing in no small measure to the success of 'traditional' economic patterns in communities such as the study villages. This section relates social capital at the community scale to the participatory paradigm. After identifying the characteristics of the social capital that occur in the participatory paradigm it explores its interactions with other systems of production at the community scale. It will be seen that communities' capital, like individuals', can act as an access mechanism to other forms. The section concludes by highlighting the particular importance of knowledge construction within the community.

2.8.1 Overlaps between traditional and participatory systems

The social capital involved in the traditional system of borrowing and sharing acts mainly at the individual and household level. As it performs a function of exchange, usually between relatively richer and poorer individuals, it is similar to bridging social capital. A different type of social capital, more akin to the bonding type, allows individuals to work in groups or share assets communally as part of a participatory solution. In this sense, the social capital that permits such community action is shared by a group of people rather than owned by individuals. The participatory paradigm is based on the notion that the social capital that allows members of households and communities to communicate, borrow and share in specially formed groups can be harnessed. Group members can use their individual social capital to relate to each other, but as they collaborate to form a new entity, the group, it thereby acquires its own stock of social capital. This emergent property of community social capital is additional to the sum of the social capital held by its members, just as ecosystems have emergent properties beyond the individual responses of their member populations (Salt 1979). If bridging social capital from the individual members can transcend scales to contribute to the bonding social capital within the group, participation also envisages that the reverse transformation can take place; the emergent social capital of the group can be transferred to and shared among members. Thus it can raise their individual capital when it is used as an access mechanism, for example to group labour or to external sources when the group applies for a loan. In this sense the source as well as the type of capital is interchangeable as it is transferred from one scale to another. In its use of social capital this paradigm draws upon the heritage of many traditional cultures and so there is a particularly noticeable overlap between the 'traditional' and participatory systems; examples are the existence of traditional member-based organisations such as age-group and hometown associations or member-funded self-help gift schemes (Gerdes 1975; Adams *et al.* 1998). Yet there is a difference between the individual social capital used in the traditional system and the groups' communal social capital. Using Woolcock's (2002) typology it is less the 'reciprocity and trust' typical in the traditional sector and is more 'reinforcing norms and their associated sanctions': a group's emergent social capital includes the ability to punish each other and abide by rules as well as its organisational capabilities. 'Opening channels of information' is another benefit of communal social capital that Woolcock cites, relevant to the construction of knowledge that will be examined later in this section. A group's social capital is usually bonding capital if the community is relatively homogenous. Another theme Woolcock does not identify but is revealed in Chapter five as pertinent to this context is leadership (Fox 1992; 1996).

The mechanisms of community social capital at the village scale can be examined through the Dagomba institution of the *kparaba* work party. In this system, groups of farmers work on each other's farms and eat food provided by the owner of the field. Work parties, some of which involve labour reciprocity, exist in different forms across Africa (Swindell 1985; Bourdieu 1986). Berry (1989) associates them with an 'accumulation of claims and clients' rather than fixed capital. This, like Guyer's (1981) phrase 'wealth-in-people', is essentially describing social capital as it cultivates access routes to potential sources of other capital. This sort of exchange is probably what prompts Woolcock's (2002) assertion that social capital is abundant and useful in SSA, a perception fortified by the cultural stereotypes of authors like Cobbah (1987) and Mpedi (2008) who cite 'obligation' , 'cooperation', 'interdependence', 'responsibility', 'unity' and 'respect' as 'African values'. The diffuse reciprocity and food sharing that happen in *kparaba* work illustrate the interchangeability of social, financial, and human capital, and implies a certain amount of local political capital. Although *kparaba* is a traditional institution, it fits the definition given here of the participatory paradigm. This is because all members of the group formally accept the agreed terms by joining in the organised activity simultaneously, whereas the less formal transactions that take place in the traditional category can often be unexpected and unsolicited. The terms of agreement of 'traditional' transactions between individuals may be more flexible, whereas the arrangement in *kparaba* is by definition more formal as it involves more than two participants. Also, although such traditional participatory institutions have long existed in West Africa, they are one of a range of structures which, as has been noted, include traditional actions involving social capital at the individual scale. It is therefore important to distinguish between this system and the idea of an entirely ‘communal’ society that was often propounded by colonialists as a justification for land appropriation. Maghimbi (1994), analysing modes of production in the Old Nigerian Ugweno state, notes that ‘cooperation’ was often for reasons of convenience and ‘cannot provide a basis to conclude such societies were communal’ (p.29).

The *kparaba* example thus illustrates that, as ever, in any one situation it is difficult to distinguish which types of social capital are involved, what roles they play and which paradigm is represented, especially when confronting the difference between the intrapersonal reciprocity of the traditional economy and the slightly more formal participatory situation. The two co-exist and interact at the community as well as the household scale. The level of formality of the arrangement is one characteristic distinguishing the two systems, and this means the participatory solution may be more conveniently expressed at the community scale and the traditional at the household. Yet actors can draw on either paradigm as they make arrangements for giving and receiving cash, labour, tools and land and this interscalar fluidity best illustrates the difficulty of distinguishing between them.

A further similarity between the participatory and traditional systems is that in neither are goods excluded from group members, so they are closer to common and public goods than the private ones that exist within a pure market. In the case of the participatory group, the concept of a semi-excludable yet non-subtractable toll or club good becomes relevant. The realisation that goods may be ‘semi-excludable’ makes it clear that it is often more realistic to place goods on a scale than to allocate them to dichotomous categories. Excludability is not a case of ‘everybody or nobody’ - between those two extremes lie groups like villages or participatory organisations.

The capitalist system explored in section 2.6.1 also co-exists and interacts with the traditional and participatory systems at the community scale - Vehnamakhi (1999) considers that in Southern Ghana, the ‘communitarianism’ inherent to intrahousehold exchange less often extends to interhousehold relationships, which are more characterised by exchanges of individuals' property. Within the livelihoods model, financial capital is not prioritised above other capitals and may simply be seen as another capital integrated into the exchange system already in existence. However, money, the universally recognised means of exchange, eventually links the local exchange market to 'the (global) Market', and one system may be an access mechanism into another. It has already been mentioned that the loans and gifts of the traditional economy can facilitate individuals' entry into formal markets: Thomas and Worrall (2002) go as far as to describe them as 'alternatives' and 'substitutes' for 'missing markets' (p.310). Indeed, they go on to demonstrate that reciprocity is in fact a major motivation in loan transactions. This can happen at the community and the household scale, and when it does may acquire the inequitable properties of the capitalist extra-household market. Cleaver (2005) shows that the poorest may not participate in many work parties because they lack not only bonding social capital with which to engage in reciprocity but also time - a permutation of labour. Bonding capital is, therefore, exclusive as well as inclusive because traditional, participatory and capitalist systems closely interlink at the community level.

2.8.2 Participation in innovation adoption

As a model of innovation adoption, the participatory paradigm emphasises the importance of the emergent human and social capital held by the community or between the community and outsiders as start-up capital, thus minimising the risks of innovation adoption (Pretty and Uphoff 2002). Although participation does not explicitly draw on Rogers' communication diffusion approach, the key tenet that farmers will design solutions appropriate to their own situation corresponds to Rogers' characterisation of successful innovations as compatible with the adopter's needs and the emphasis he places upon the 'trialability' and 'observability' of the technology. 'Interconnected', communicative societies with strong bonding social capital are posed as more likely to adopt innovation. Identification of a rich elite of 'innovators' in the participatory literature (Reij and Waters-Bayer 2001; Uphoff 2002) corresponds to Roger's first group of innovators in the diffusion model (Rogers 1983; Ghadim and Pannel 1999; Gebre-Michel 2001; Nielsen 2001). This is another factor informing the critiques of participation and diffusion discussed earlier.

The participatory response to this critique is that the model emphasizes 'bottom up' rather than 'top down' action because the start-up capital and decisions as to how it is to be used stem from the farmers (Morris 2000; Douthwaite *et al.* 2001). As such, participation is empowering and using the model on the basis of efficiency alone is extractive and apolitical. A political slant is also introduced in the common caveat that an 'enabling policy environment' must exist (Hinchcliffe *et al.* 1995; Fox and Gershman 2000), thus acknowledging the influence of governments and the state. A similar sentiment is expressed by those organisations like AGRA that promote the formation of a capital market, although in their case the ultimate goals are modernisation and technological 'progress' through commercialisation of agriculture. In the case of the 'enabling policy environment' for participation, if the 'true' participation indicated by Petty's (1995b) category of 'self-mobilisation' is really what is to be 'enabled', the aim is not necessarily to promote modernity but to allow the participants to pursue whatever strategy they wish. As suggested above, this is usually the rhetoric if not always quite the reality.

In reality, normative arguments may seem less relevant when there is a need for pressing action. Gebre-Michel's (2001) observation that farmer innovation may replace extension if there is little state input highlights that if the necessary start-up capital is not available from an external source, collective action may provide the only means of adopting a new innovation. If a community adopts participation on this basis, it may be superfluous for a facilitator to advocate 'empowerment' that farmers deem unnecessary. Adhikariya's (1994) FAO publication illustrates this schism between efficiency and empowerment - he advocates the addition of participation to extension programmes in situations where resources are lacking. Presumably this is a cost saving measure, but the dilution of the participatory ideology this implies is incompatible with its stated aim of empowerment.

2.8.3 Community capital as an access mechanism

The emergent social capital of participatory groups functions not only as an additional capital to exchange between members or even groups, but can also be described as another mechanism of access to the capital held by the individual members. One of the main advantages of gaining access to human capital in the *kparaba* work party is timeliness, a concern absolutely central to agricultural practice (Berry 1993). As an example, hundreds of person-hours of clearing and carrying compost to the field need to be done before the rains (Swindell 1985). Timeliness is the main reason for the use of human capital on a community scale in a low technology (physical capital) environment. There are many examples of the necessity of timely group work in a system where comparative advantage in terms of skills (human capital) is low. Wet seeds must be sown at the most two days after rain so they can germinate in the residual moisture. If weeding is not performed at a critical stage in the crop's development its yield will be threatened, hence groups of young men work in teams to stagger their groundnut sowing and thus the first and second group weedings. If produce is not removed from the field within a day of harvest it begins to spoil. Non-agricultural situations also illustrate this: when a house is roofed, all men in the village congregate in order to complete the task in one day. If not, the owner of the room would not be able to sleep in it that night. Once again the importance of working within the agroecological context is evident, and it is the pressing need for timely practice that makes participatory and traditional access to group labour so important. In this respect, community scale social capital is a central pillar of successful agriculture practice for reasons linked to efficiency rather than empowerment.

Such social capital also gives access to financial capital held by members of participatory groups. Izac (1997), Malmberg-Calvo (1998) and Sanchez *et al.* (1996) advocate the Word Bank's solution of cost sharing for transport and SFM techniques on the basis that the beneficiary should pay. This has included cash contributions from villagers as well as group labour. Individuals hold those capitals but it is the organisational structure consisting of group social capital that facilitates access to them. Groups may also be more likely to gain access to capital available from external sources, for example the fertiliser credit packages offered to Ghanaian maize farmers by the Millennium Development Agency. Here bridging and linking social capitals are crucial. Groups can also purchase physical capital for which individuals lack the means. Community ownership of goods was claimed by 64% of farmers in a Ghanaian survey to be preferable to individual ownership (Anchirinah *et al.* 2000). This may be firstly because the economies of scale involved meant access to large items like carts was possible and secondly because the mechanism of access to such capital appropriated pre-existing organisational structures like work parties with which the farmers were already familiar. Similarly, the ownership of shea butter mills by women's cooperatives in the West African Savanna builds on the group organisation of shea butter production (Wiemer *et al.* 1989; Harsch 2001; Greig 2006).

The slight differences in the type of social capital used in the participatory and traditional approaches have already been described. The participatory approach differs from the traditional economy in a further respect. Whereas the transactions associated with the traditional economy involve access to individuals' financial and physical capital, in addition participation emphasises the exchange and creation of knowledge - a type of human capital - between peers. This is another aspect of the emergent human capital of the community, one which can be more easily created at this scale than financial or physical capital.

2.8.4 Knowledge creation

As well as the organisational benefits of accessing more cash and labour power, sharing and construction of knowledge are emergent capitals undeniably held at the community scale. These are emphasised by participatory authors, although the process of knowledge creation is usually initiated by an investment of time or knowledge from an external facilitator like the NGOs and Ministry of Food and Agriculture (MOFA) who taught composting in the study communities (Tosun 2000). Thus Nederlof and Dangbégnon (2007) note that farmers teach each other, but it should be acknowledged that in their study, as others, this occurred within a SFM project facilitated by an extension-NGO partnership. On the other hand, 'indigenous' knowledge has been constructed over hundreds of years to produce longstanding SFM strategies: those cited in Uphoff's (2002) and Reij and Waters-Bayers' (2001) collections include *zai* depressions in Burkina and planting maize in *wafipa* pits in Tanzania (Malley *et al.* 2001). Farmers may therefore articulate that new SFM strategies add nothing to their knowledge (Omosa 2002). Some participatory authors valorise such 'local' knowledge. However, those who emphasise the importance of farmers and 'outsiders' learning together point out that the two parties may co-construct useful knowledge during that process. Somda, Nianogo *et al.* (2002) felt that extension had added little to farmers' pre-existing knowledge of SFM, but new stock management training facilitated crop-livestock integration and thereby indirectly helped improve soil fertility. Such co-constructed knowledge is particularly relevant in the case of new intensification measures, for example those responding to population density increase. Farmers in the Kano close-settled zone have perfected their system of manuring over hundreds of years (Mortimore 1998). Harris and Yusuf (2001) note that long experience has developed expert knowledge, but 'participatory trials' could improve manure management as the system encounters increased pressure, for example reducing leaching by stockpiling manure more briefly or on an impermeable surface. The co-construction of such modern and appropriate knowledge is surely always relevant in a constantly dynamic environment (Defoer 2002). It is an emergent social and human capital of the relationship between researcher and participants and is further evidence that, as capital is rarely located in a single actor, development strategies must consider elements of all paradigms.

In a similar pragmatic vein, the emergent organisational benefits of community capital are not appropriate at all scales for practical reasons. Farmers in Burkina formed groups for sharing the labour costs of pit digging, but not for conveying compost to individuals' fields (Ouedraogo *et al.* 2001). The most appropriate primary source of capital varies for different tasks within a process, and must often fit within existing social formations, for example those relating to land ownership.

Just as community capital may act as an access mechanism to that held by individuals, such interscalar relationships also extend beyond the community. Participation is now the dominant development paradigm (Cornwall and Brock 2005) and government agencies like Ghana's Ministry of Agriculture have adopted aspects of it. Yet both NGOs and government are agencies external to the community, and both must invest some human capital in the form of time or expertise to facilitate education or 'learning' within it. Therefore some capital comes from outside to give access to the community's local capital, and it can be seen again that the sources of capital are interchangeable, not only between community and individual but also in the relationship between the community and external agencies such as the state.

2.9 The State's capital

As well as its more recent indirect role as an 'enabler' of capitalism and participation, the state may alleviate capital constraints at the individual level by direct and indirect investment. Both of these are usually facilitated by financial capital and the ability of the state to provide them will be examined in this section, followed by further examples of how capital inputs from certain scales and systems may facilitate the development of others.

2.9.1 Direct investment

The most direct injection of capital from the modern state to the farmer is the subsidy. The 2008 Ghanaian fertiliser voucher, instituted in the run up to the general election, is an example of how the state's financial capital can enhance the individual farmer's ability to purchase inputs (Erenstein 2006; Smaling and Dixon 2006). In 2010, the year in which the bulk of the data for this study was collected, the voucher was replaced by a general subsidy - centrally subsidised fertiliser was sold from outlets at a 40% reduced price of 18GhC (£7) per 50kg bag of Sulphate of Ammonia and 27 GhC (£10) per 50kg bag of Compound fertiliser. This was continued into 2011, when a 42% subsidy reduced the price of compound to 30 GhC, ammonia to 25 GhC and Urea to 29GhC per 50Kg. This switch to an at-source rather than a voucher model pushed the subsidy in the direction of becoming less subtractable and more of a public than a common good. The subsidy became more accessible to farmers than it had been under the voucher system, notwithstanding the fact that fertiliser itself, once purchased, remained a subtractable, excludable private good. In theory, public goods are non-excludable, although the subtractable nature of scarce resources means that those in positions of power are often able to make them so. Schemes to provide physical implements, like the tools used to turn compost, although rare, would have a similar positive effect on smallholders' ability to carry out livelihood activities.

Kachule and Chilongo (2007) show that states and markets interact if subsidies establish other markets, like that in the illegal cross-border trade of subsidised fertiliser from Malawi to neighbouring Tanzania, or cocoa from Ghana's Volta region to Togo (Baker 2000). Credit services to individual smallholders could also stimulate markets as they purchase goods and services such as ploughing. In a market situation, the most obvious aspect of individuals' capital that affects inputs is financial - as noted earlier a scarce resource in SSA (Lebo and Schelling 2001). It has been seen that capitalist markets do not fully meet smallholders' needs in that they are unlikely to provide for the poorest. This, as well as the uneven balance between the state's ability to influence the capital of the smallholder and the smallholder's effect upon the state, leads to the normative socialist stance that the modern state should have responsibility for such direct development and the welfare state should underpin people's basic needs (Gough 2000).

In the era of independence, Nkrumah's idea of African socialism took such a normative view that the state should be the agent through which investment was directly provided to the people. Like the structural critique of the diffusion model of the GR (Galjart 1971; Goss 1979) and later critiques of participation (Cooke and Kothari 2001a; Williams 2004) African socialism, like its European counterpart, saw a role for the state in providing capital to farmers and criticised the bias of the market towards those already owning individual financial capital. However although subsidy, fixed prices and parastatal marketing boards were policy features, agriculturalists' terms of production were not directly improved because the Ghanaian version of African Socialism prioritised industrialisation (Rooney 1988; Rahman 2007). Bates (1981) has described how early post-colonial African policies tended to favour urban constituencies, and Nkrumah's high taxes upon export goods led to discontent, particularly amongst cocoa farmers in Southern Ghana (Biney 2011), although they had less effect on the Northern subsistence farmers upon whom this study focuses. Crucially, the realities of African states' low capital capabilities meant that the main thrust of African socialism was that, initially at least, external investment would be mediated through the state towards industrialisation projects like the Volta river scheme (Esseks 1971; Das Gupta and Shahid 1981).

The importance of foreign capital meant that immediate post-colonial development policy retained vestiges of the colonialist capitalism it eventually aimed to eradicate (Grundy 1963). This mixed economic model is an example of how elements of different systems are appropriate in different contexts, and the most 'convenient' or 'efficient' solution must often be pursued in situations of scarcity even if it is ideologically unpalatable. Nkrumah's policy of foreign investment also left significant room for rent-seeking and nepotism (Bretton 1966; Jeffries 1982; Rooney 1988). The propensity of such failures to increase the excludability of subtractable goods became commonplace in the 20th century Ghanaian '*kalabule'* black market system of informal and illegal supply of banned goods (Goody 2007a) with Safro (1983) opining that the tendency of such systems to develop in SSA was a result of allowing market traders to act upon their capitalist profit maximising ideologies in a situation of relative scarcity. Public goods thus became closer to private ones as the state's inability to supply sufficient capital combined with corruption to create a very imperfect capitalist market.

Direct investment from the Ghanaian state was undermined by corruption such as *kalabule* and the system faltered through successive regime changes until economic collapse and the introduction of SAPs in the 1980s, readjusting the focus of state intervention to indirect investment. Recent governments have introduced more 'farmer friendly' policies, mostly encouraging market integration strongly supported by the state, like 'smart' or targeted subsidies, e.g. implemented through vouchers.

In comparison to the story of state involvement in post-independence Ghana, the Asian 'Tiger' economies also experienced interventions from the 'developmental state' (Leftwich 1994; Hart 2001), but in their case laid more emphasis on indirect investment. This can occur through trade and investment policy - taxing imports, restricting or promoting foreign investment and adjusting the relative prices of farm and consumer products (Dicken 1998) - all affected by the extent of structural adjustment. Tax relief on export goods can raise the price of cash crops, freeing cash flow for individuals. Relevant to the subject matter of this thesis, authors from the Animal Traction Network for East and Southern Africa (ATNESA), like Ellis and Hines (1998), advocate similar policies such as reducing import taxes on imported goods such as cart axles to improve Sub-Saharan African farmers' access to those means of production. Gershon *et al.* (1985) and Bardhan (1979) consider that the state has a role to play in encouraging adoption of new technologies by thus affecting costs and prices of goods to change the profit margin. Similarly, Clay *et al*. (1998) state a need for improved infrastructure and education, large scale functions best provided by the state and Harrison (1994) accuses poor service markets as being responsible for low agricultural innovation adoption. Such market tools became significant as the Rawlings administration accepted SAPs in 1983 (Amanor *et al.* 1993) and these impacts worked their way down to the smallholder through the market as input and output prices changed. When a government liberalises the economy in return for loans, the boundaries between state provision and the role of the pure market become blurred, and the inequitable effects of the latter can come into play. For example, Gray (2005) describes how providing extension services to cotton growers in Burkina Faso started to prioritise the farmers able to afford the risks of a loan, because cotton requires chemical inputs.

2.9.2 The 'enabling environment'

It has been illustrated how one actor may facilitate the development of capital located within another. Nowadays reform neoliberals and especially participatory writers espouse this idea, and as described earlier it is common to read that the state should provide an 'enabling policy environment' (Hellin and Schrader 2003; Kuyvenhoven 2004) in order to promote participatory or sustainable agricultural development. Despite varying degrees of specificity about what exactly this means, it usually involves combining elements from traditionally disparate development paradigms. Thus Kuyvenhoven and Ruben (2002) and Sanchez *et al*. (1996) advocate market liberalization *as well as* public investment, whilst Pretty *et al.* (2002) warn that whereas input price subsidies 'induce perverse or skewed effects' (p.257), there is a place for 'selective incentive regimes attuned to local conditions' and 'public investment in infrastructure', potentially encompassing 'smart' subsidies. Development and service provision can be 'encouraged' and 'promoted' by subsidising fertiliser but also by reducing taxes, funding research, improving infrastructure or privatising services. Sector-specific policies may also be relevant: imports of cotton could be taxed but axles may not (Reddy 1988). Rasul and Thapa (2004) and Kuyvenhoven (2004) argue that in order to promote sustainable agriculture the fuel used for transport, but not that used for the production of inorganic fertiliser, should be subsidised. It may therefore be more relevant to emphasise the type of capital provided, the sector it supports and the type of solution it engenders rather than its provenance or the system through which it was supplied. Participatory authors thus emphasise the regenerable nature of human over financial capital, regardless of the route through which it is provided: it is less risky and more flexibly converted than targeted investment or subsidy, and investing in human capital rather than the market buffers the risk of unpredictable shocks. The efficiency argument for participation is also relevant. Although socialist authors took a normative viewpoint toward the promotion of state provision, budget constraints mean in the African context this is often unachievable: another reason for the consensus between participatory and reform neo-liberal commentators that indirect provision - the 'enabling environment' - is more appropriate.

It is indisputable that there are some interventions that need large amounts of capital and are so extensive that they require planning on a grander scale than that of the individual or the community. Transport infrastructure is an obvious example (Porter 2002). Its provision has the potential to improve livelihoods directly and can alleviate spending other forms of capital held by the individual (Onduru and Du Preez 2008). Improved roads facilitate market access, save time, minimise wear on vehicles and may provide opportunities for expansion of a transport market. Similarly, raising human capital by investing in programmes like Ghana's National Agricultural Employment Programme and training extension staff is often most effectively coordinated at the national scale. The State's access to more financial resources provides physical inputs beyond the reach of the individual and most communities and it may also have better facility for inter-agency liaison (de Jager *et al.* 2004). The state can operate at a range of scales - Ghana has district and regional levels of government which are probably better decision making levels for specific development activities.

The international relationships that the state is engaged in mean that issues of access to financial capital transcend even the national level. Although individuals and communities can definitely source international capital directly, for example through remittances and NGOs, the state's international relationships enable it to access capital held abroad more easily. As well as the financial capital of aid, agreements brokered between governments give the state access to the knowledge required to build the human capital of experts and professionals like engineers and extensionists. For example, one way in which Ghana benefits from Cuba's policy of South-South cooperation is in the medical scholarships it has granted to Ghanaian students. According to Ghana News Agency (GNA 2012) 250 students departed in May 2012, gaining access to the skills and knowledge held in Cuban universities. Meanwhile, Cuban doctors serve in Ghana, like the 79 who arrived in November 2010 (GNA 2010)

However, as Woolcock (2002) notes, social capital or the lack thereof does not always act in a positive direction: structural adjustment provides an example of an instance where the state's *lack* of political and social capital affected its access to financial capital in a way that was not immediately beneficial to farmers.

So political or social capital is not always exchanged itself but acts more as an access mechanism to capital in other locations. This is another example of how difficult it is to distinguish between the sources of capital, depending on the scale at which the analysis is taking place. To the farmer who eventually receives this capital, for example as a result of meeting an extension officer or NGO worker, its original source may be less relevant, but at the macro-level it is important to distinguish the mechanisms through which the state accesses such capital. At this scale the mechanisms are undoubtedly political and involve bridging social capital between states and other agencies. The state is not politically neutral, confirming that political capital is an important part of the livelihoods framework (Scoones 1998; Baumann 2000). Equally important, the state acts on a large enough scale to organise such major endeavours. If the state lacks the organisational capacity, or is unwilling to use it, there really is no solution for the individual farmer, who cannot self-mobilise to provide services such as formal education or road building. So the state's capital is necessarily implicated in large scale infrastructural development.

2.10 Capital from NGOs and international agencies

Ultimately, however, the state often 'disengages' from development interventions (Starkey 1990) with the end result that financial capital rarely stretches all the way from the government to the smallest scale interventions on the ground. It is very unlikely, for example, that municipal bicycle paths will be found in the Ghanaian countryside as they are in European cities for the foreseeable future. This could be ascribed to a lack of organisation or lack of demand, but essentially, even if they existed, a lack of financial capital would be the ultimate constraint. If neither the state nor the individual can provide the requisite capital, many see this as the role of international donors - both supposedly apolitical NGOs and foreign governments. This study primarily analyses capital interactions at the village level and will not attempt a detailed analysis of the role of NGOs in developing states. However, this section is the place to tackle briefly the vagueness around the ‘favourable conditions’ for development by comparing the roles of developing states and donors.

Governments, but not NGOs, can affect trade policy and subsidies - although political pressure affects what line the state will take. Governments also have some measure of political capital that many, especially smaller, donors do not. However, this does not mean that the latter cannot access the human capital available to states: NGOs have access to skills, labour and knowledge from informal associations and may also access money through routes unavailable to states, e.g. philanthropic giving. Some, but by no means all, can be more efficient and accountable. When the state and NGOs act together at the village scale (Alibikiya 1993), it can be less relevant to distinguish between them, for example in the joint SFM research and development project between MOFA and the International Fertiliser Development Centre (IFDC) in the study district of Tolon Kumbungu (Clottey *et al.* 2006). The participatory literature in particular emphasises the importance of personal skills for knowledge building and adaptability and much depends on the individual extension or project officer. Nonetheless, within Ghana’s MOFA there is an overriding perception that NGOs have more access to financial capital than the government does (Kolbilla and Wellard 1993).

Just as capital can flow between farmers and agencies external to the community, it also flows between these agencies themselves. The most notable example at the macro-scale is the exchange of capital from international donors to governments. After President Rawlings accepted SAPs in the 1980s, proponents of this strategy hailed Ghana’s subsequent economic growth as a success. However, broadly speaking, structural adjustment aims to make a nation more efficient by bringing it into the global capitalist marketplace, and it has been seen that this disadvantages the poorest. The most relevant examples of this are the removal of fertiliser subsidy, the downscaling of the extension service and the reformulation of state marketing boards, improving access to the international market but simultaneously removing a safety net for those who cannot compete in it successfully. There are mixed assessments of the effects of SAPs in Ghana - although GDP (Kraus 1991) and agricultural output have grown at the national scale (Boafo-Arthur 1999) these are not necessarily measures of success for all. The inequitable effects can be seen as a mark of failure (Kuyvenhoven 2004) especially in the continually economically marginal North of the country

(Konadu-Agyemang 2000); the creation of the Ghanaian Programme of Actions to Mitigate the Social Costs of Adjustment is recognition of this (Simon 2008a).

2.11 Coproduction

The overriding theme of this chapter thus far has been the coexistence and interaction of the various different forms of capital, routes of access to them and the paradigms they suggest. This echoes Marx's description of how modes of production 'articulate' as they succeed each other. Even the colonial Gold Coast state recognised the benefits of such interrelationships in its policy of governing through existing indigenous institutions (MacLean 2002). This arguably promoted mutual facilitation between some elements of traditionalist and capitalist forms of organisation: the appropriation of traditionalist clientist and patronage structures by colonialists for the purposes of land appropriation has been termed 'neo'colonialist (Nabudere 1999). A more recent expression of a similar concept is Ostrom's (1996) 'coproduction': synergy between state and 'community' in providing services. A West African example of this is the participatory Nigerian Awe Development Corporation obtaining use of a subsidised government-owned tractor (Barkan *et al.* 1991). By definition, coproduction gives smallholders access to services (Ostrom 1996; Joshi and Moore 2004); the concept recognises that interaction between different actors is often necessary to implement beneficial change .

This finds expression in the aforementioned emphasis upon the 'enabling policy environment' (Ribot 1995; Bationo *et al.* 1998a; Kuyvenhoven 2004). In explicit recognition of the benefits of coproduction, some African states have attempted to integrate the participatory paradigm into state machinery. The East Asian example has been copied as Farmer Field Schools are incorporated into agricultural extension (Simpson and Owens 2002), with varying degrees of success. Examples of state interaction with the private sector are found in subcontracting agricultural extension (Umali-Deininger 1997) and public-private partnerships like the Ghana Grains Partnership (Guyver and MacCarthy 2011). As described, indirect state support to private entrepreneurs like farmers in the form of appropriate pricing policies and adequate infrastructure also encourages their integration into the private capital market: in testing the validity of their Kenyan 'Machakos hypothesis' of agricultural intensification in West Africa, Mortimore and Tiffen (2004) emphasise how important policy is in encouraging farmers to invest in resources like soil. Participatory and capitalist paradigms interact extensively. The central role of social capital in participation and its facilitation of neoliberal policy has been noted, and practical expressions of this relationship abound: farmers' associations improve producers' terms in their negotiations with traders, for example in the Ghanaian vegetable market (Boateng *et al.* 2007; Robinson and Ngeleza 2011). A three-way relationship emerges when such market entry is encouraged by the state: Ghana's Food and Agriculture Sector Development Policy (MOFA 2007) lists amongst the strategies to achieve 'increased growth in incomes' the 'formation of viable farmer groups and Farmer-Based Organisations ... for stronger bargaining power in marketing'. Despite the critique that this represents co-option of the participatory ethic by the exploitative elements of capitalism, on balance, the evidence suggests that interaction between state, market and civil society has positive outcomes for smallholders' agricultural development. The traditional system also has a role to play in this, yet it is difficult to find explicit examples of its interaction with other paradigms. This is because, due to their extensive overlap, the literature seldom distinguishes between traditional and participatory systems: as explored in section 2.8.1, it would be very difficult to assign West African age group, Asafo and home-town organisations and possibly even work parties exclusively to either of those two paradigms, and even more so the links and transactions between individual members of those groups. In reality, actors interact in multiple ways and co-existence and indeed synergy between paradigms is ubiquitous. Ostrom's idea of coproduction confirms that elements of one system do facilitate the other.

2.12 Capital in Northern Ghana

Having reviewed the various coexisting and interacting types and sources of capital potentially available to Dagomba farmers, state statistics give some information about the extent to which they are accessible to smallholders in the study area.

Table 2.2 shows the only data to be presented by region in the 5th and most recent Ghana Living Standards Survey, indicating that the three Northern regions have the lowest levels of financial and physical capital. Table 2.3 adds to this with some selected data for the study communities, showing that they experience a moderate level of development, having limited access to markets, education, fertiliser, cash, tools and labour.

Table 2.2 Selected indicators of capital by region.
Sources: (1) Ghana Statistical Service (2008) and (2) Ghana Health Service (2008).

Region	6-25 year old school attendance (%)(1)	Rate of health insurance coverage (%) (1)	Mean p/c expenditure (GhC) (1)	Household income from agriculture (%) (1)	Number of healthcare facilities (2)
Northern	*54.7*	*4.1*	*362*	*68.5*	*168*
Upper East	61.2	4.9	229	56.9	174
Upper West	64.1	3.0	166	50.1	154
Accra	94.7	6.7	1050	5.0	384
Ashanti	95.2	11.0	682	20.9	530
Brong Ahafo	89.4	17.2	514	56.5	220
Central	95.9	7.4	676	37.7	158
Eastern	94.3	10.2	613	42.4	132
Volta	85.9	3.7	491	40.4	No data
Western	93.0	6.2	648	45.1	261

Table 2.3 Characterisation of the study communities in 2010.

	Ypilgu	Zaazi
Water	Pipe, dam	Borehole, dam
Electricity	No	No
Toilets	No	Built, not used
School	Constructed in 2009	No
Road	Second village along dirt road, 3km from tarmac road at Kumbungu town	Dirt track 1 km from Savelugu-Kumbungu dirt road
Nearest market	Weekly , Kumbungu	Weekly, Savelugu, also Kumbungu
Distance from Tamale regional capital	18km, Occasional road transport from Kumbungu on market day	20km, transport from Savelugu
NGOs: their activities	Opportunity Industrialisation Centre: livestock, sanitation, composting. Centre for Agricultural and Rural development: fertiliser loans	Simli Aid: composting, literacy, advocacy. Two other NGOs: vegetables, livestock, women's group

The state does have infrastructural input into the North of Ghana, albeit at a lower level than the South, and this is supplemented by the activities of NGOs and private capitalists, for example in provision of transport services and markets. Notwithstanding this, as Chamberlin *et al.* (2007), Shepherd *et al.* (2005) and Al-Hassan and Poulton (2009) note, the fairly low physical and financial capital available to Dagomba farmers restricts their ability to substitute for the relatively unavailable natural capital of the West African Guinea savanna.

2.13 Community and social capital as a practical solution

The interchangeability, co-existence and multi-functionality of the types and sources of capitals people use in their livelihood strategies has been illustrated. Despite the apparent multiplicity of available sources, farmers still face capital constraints. The uncomfortable facts are that the state's capital either does not extend to or cannot be accessed by the majority of farmers at the smallest scale, donors are often unreliable and most individuals lack the capital necessary to take the risk of relying on the inequitable market, thus also precluding the traditional system that relies on individual ownership. Participatory authors and increasingly reform neoliberals therefore locate the missing capital as social capital or capital within 'the community' (Porter 1997; 2002) thus implicating the participatory paradigm on grounds of efficiency.

Advocating participation because of its efficiency alone may absolve the state and the international donor community from responsibility for development and excuse market mechanisms (Bowles and Gintis 2002; Cleaver 2005). However, many farmers are obliged to adopt elements of this solution simply because it is more expedient than others. In addition, where financial capital is lacking, the emergent qualities of community knowledge creation that form part of the participatory system are particularly relevant. In any case, ultimately, having access to a range of solutions and the flexibility to choose between them in different situations is more important than using only the apparently accessible participatory solution, because a mixture of capitals facilitates adoption of appropriate technology.

2.14 Excludability, subtractability and ownership

A typology of goods based on their excludability and subtractability is inextricably tied to resource ownership by different parties, and these notions are therefore useful in explaining how and why those different types of ownership are more or less appropriate in different situations.

The form of ownership of a resource and the source of capital it may require affects excludability more than subtractability, and goods may exist at different points on the excludability scale in different situations. Thus, as pressure on resources like farmland grows and market integration evolves, the 'individualisation' of formerly common resources (Bryceson 1999a) becomes more apparent. Greater subtractability creates an incentive for private ownership and hire of toll goods, and as more goods become privately owned and excludable this creates the preconditions for the development of a capitalist ownership and hire system. However, participatory systems are an alternative occasionally pursued if communities decide to respond collectively and use toll and club goods as a coping mechanism in conditions of resource scarcity.

Such conditions of resource scarcity mean that the subtractability of goods becomes more important. Subtractability impacts upon excludability and is generally defined by the characteristics of the good itself. Those goods that can be more easily shared may be more amenable to group or community ownership, which would mean the capital for their procurement would be sourced from the community or household. However, as pressure on resources rises, more of those goods that appeared public may tend to display 'common' characteristics of higher subtractability. This invokes Hardin's (1968) Malthusian 'tragedy of the commons'. The political ecological response to that narrative will be examined in more depth in Chapter three.

2.15 Summary

This chapter has constructed a theoretical framework for the examination of the ownership of physical capital farmers use in their livelihood strategies. It has distinguished between different sources of capital, relating them to four different systems or paradigms under which capital is made available to farmers to pursue their agricultural activities. The livelihoods concept is acknowledged as a useful foundation, bearing in mind critiques that it, and the concept of social capital in particular, is apolitical and inherently capitalist. The liquidity of livelihood capitals demonstrates that it is often difficult to determine the original source, or indeed type, of any particular type of capital exchanged by and between individuals.

The market and traditional systems that rely on individual ownership often cannot be enacted in the low capital conditions commonly prevailing in SSA. Similarly states do not always provide enough capital. The participatory solution is therefore implied on the grounds of efficiency. However, most important is to have access to a range of mutually facilitating capital systems, because the differential subtractability and excludability of various resources means different ownership systems are important for each resource.

Throughout the chapter, the importance of such context specificity has been repeatedly observed. The constraints of site-specific seasonality force the issue of timely access to source of capital, confirming that in any one situation a range of coexisting systems for innovation adoption and development may be implicated (Douthwaite *et al.* 2001), as much on the grounds of practicality and convenience as ideology.

Sustainability is a further important agroecological concept that influences the appropriate innovation to adopt. A strong sustainability standpoint considers that certain crucial types of natural capital are not interchangeable with others. This contrasts with the capital liquidity of the livelihoods model. These concerns will become more important in Chapter three, which considers the sources of capital necessary for different Soil Fertility Management and intermediate transport strategies.


Loading compost in Ypilgu

Chapter Three

Capital sources for Soil Fertility Management and intermediate transport

3.1 Chapter structure

Chapter two described the different types of capital necessary for smallholders to adopt and practice agricultural innovations and livelihood strategies. These capitals are derived from different sources, and the substitutability of types and sources of capital illustrate the co-existence of capitalist, statist, traditional and participatory systems of access to them, each associated with different development paradigms. This chapter will begin to tie these concepts to the particular practical and geographical situation of this thesis, the linked areas of Soil Fertility Management (SFM) and intermediate transport (IMT) in Northern Ghana. It begins by describing the background to the study, explaining how Dagomba farmers have intensified and diversified in order to overcome the natural capital limitations of their savanna environment before considering how academic approaches to tropical soil fertility in general have changed over time. This will be examined through four bodies of literature, relating to nutrient balancing, political ecology, participation and finally specifically to Integrated Soil Fertility Management (ISFM).

Although these are not discrete, or indeed the only, ways of examining soil fertility, they are particularly prevalent in the literature on African soils and illustrate the extent of interdisciplinarity in the development of the debate. The literature is presented chronologically in order to demonstrate how the thinking on SFM has been affected at different times by the four development paradigms introduced in Chapter two, and how that thinking has in turn affected SFM research methodologies and practice. In doing so, the chapter illustrates how socioeconomic and agroecological research, thinking and practice interact, and in particular how the political context of research affects how agroecological perceptions are formed. It demonstrates what (little) researchers know about the nutrient dynamics of Guinea savanna agroecosystems and considers the vital role of Soil Organic Matter (SOM) in this unpredictable precipitation regime. The chapter ends by summarising the SFM and introducing the IMT strategies that form the focus of this thesis. The concepts of strong and weak sustainability are applied, in that although some of the functions of SFM solutions are not interchangeable, the capitals used to facilitate them can be. Through this, it further illuminates the extent to which the livelihoods framework can be useful as an analytical tool. This lays the foundations for the research questions introduced in Chapter one on how to facilitate effective IMT for SFM in Dagbon. The themes of context specificity of forms and sources of capital and the coexistence and interaction of paradigms continue to recur.

3.2 Low natural capital in the Guinea savanna

Compared to more northerly Sudan Savanna and Sahel areas of West Africa, the Guinea savanna has a reasonable amount of annual rainfall and pockets of manageable soils. Figure 3.1 situates the study site within the Guinea savanna zone. However, more important than the absolute amount of natural capital is the way in which its unpredictable and irregular distribution over time and space constrains farmers' productivity.

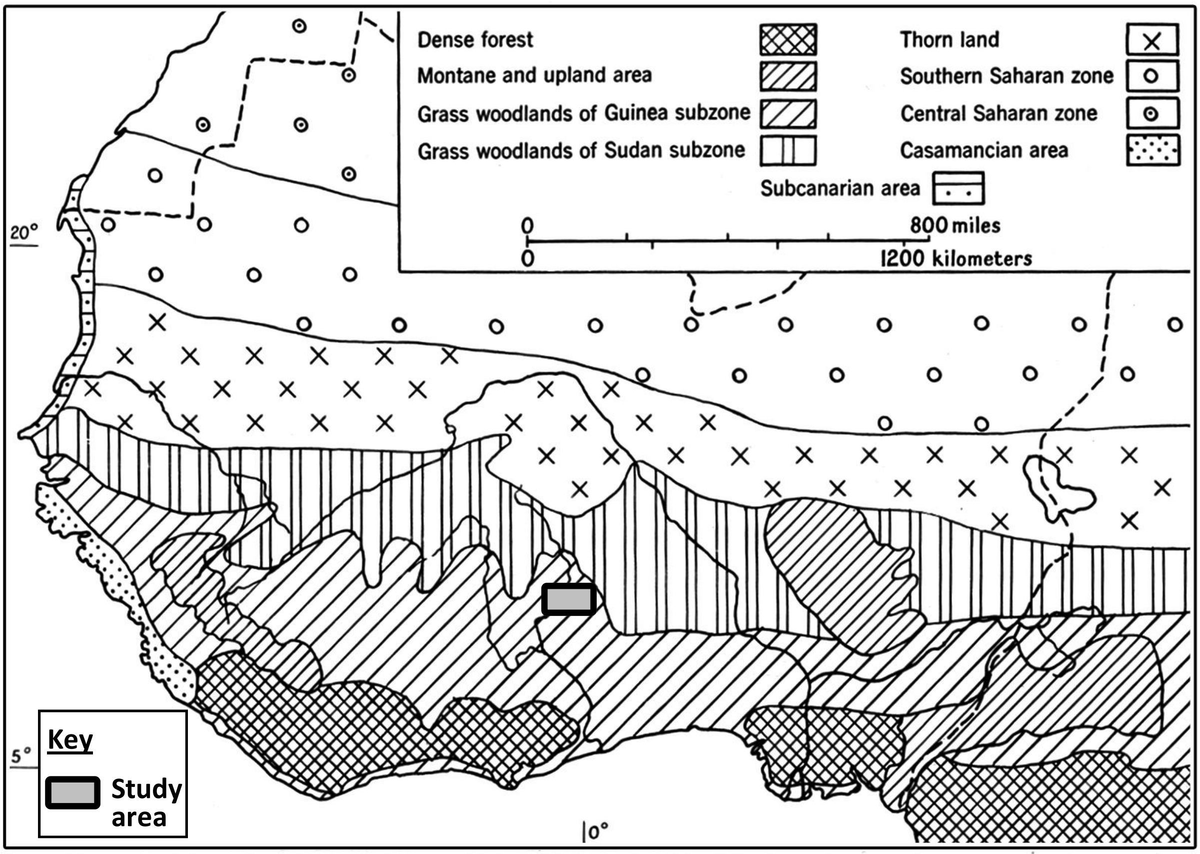

Figure 3.1 Northern Ghana within the West African Guinea Savanna zone.
Source: Stamp and Morgan (1972)

West African soils are generally geologically old, highly leached and thus low in nutrients (Irvine and Ahn 1970; White 1997). All tropical soils of West Africa are sandy and low in organic matter (OM) and include the poorest quality luvisols (FAO 2005), oxisols and ultisols (Fitzpatrick 1986) (See figure 3.6b). Those of the savanna lack the litter layer more often found in the forest zone. The specific soils of the study site, described in section 4.1, share these qualities. They retain few plant available nutrients and little moisture. Traditionally, shifting cultivation and then bush fallowing gave farmers access to new areas of more fertile soil or allowed fertility to regenerate (Nye and Greenland 1960). In the current sedentary agricultural system a source of fertiliser is needed to replace the natural nutrient capital removed by annual cropping.

Figure 3.2 shows that rainfall is a further factor constraining savanna agriculture. Stamp and Morgan (1972) give a regional range of between 1020 and 1525 mm precipitation/yr; more significantly this rainfall is monomodally distributed, limiting agriculture to a single growing season concentrated between May/June and September/October (figure 3.3).

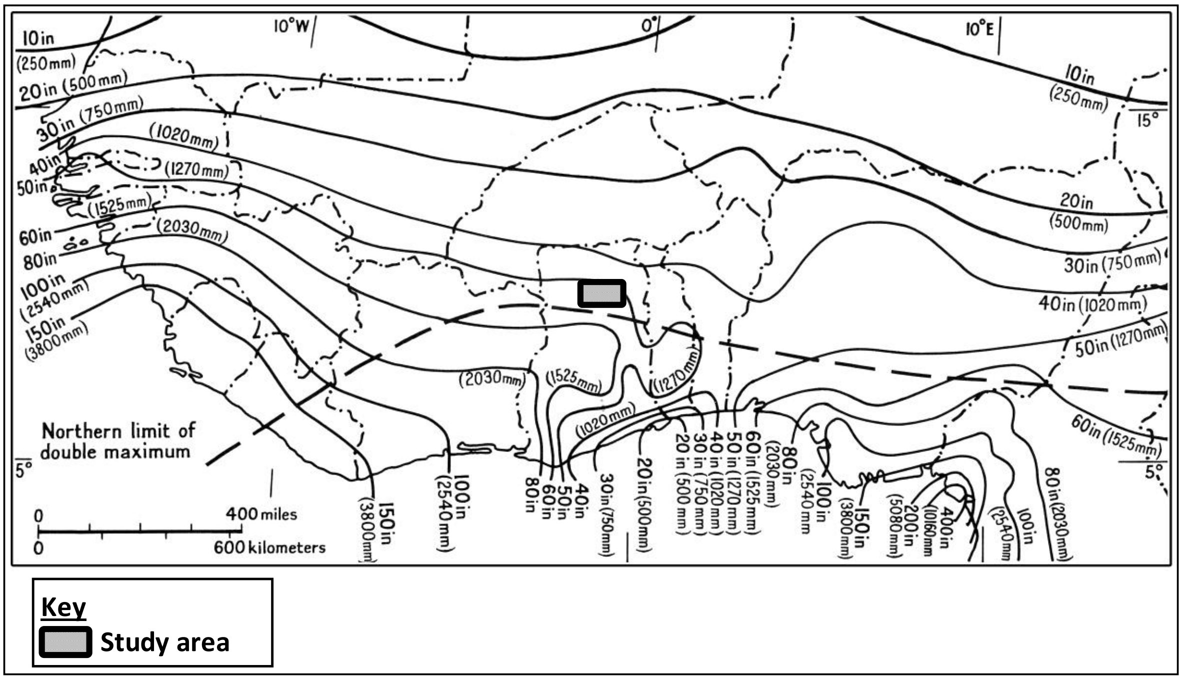

Figure 3.2 Map of rainfall isoclines and boundary of rainfall modality in West Africa.
Source: Stamp and Morgan (1972).

	J	F	M	A	M	J	J	A	S	O	N	D
Rain			Maybe	Rain		Maybe		Rain		Maybe		
Maize												
Millet												
Yam												
Cassava												
Groundnut												
Malapinta Groundnut												
Beans												
Vegetables												
Composting												

Key:	Rain	Possible rain	Activity	No Activity

Figure 3.3 Dagomba farming calendar.
Source: Bellwood-Howard (2009).

A comparison of figures 3.1 and 3.2 with the soil maps shown in figure 3.6 demonstrates that rainfall, rather than soil type, determines the site's classification as a sub-humid Guinea savanna site.

The variability of precipitation is a significant constraint (Sultan *et al.* 2005) across the whole of sub-humid and semi-arid West Africa: figure 3.4 shows the unpredictable nature of the inter- and intra-annual regional rainfall. Such variability makes itself felt most acutely in years of low and unpredictable rainfall such as 2007 in Dagbon.

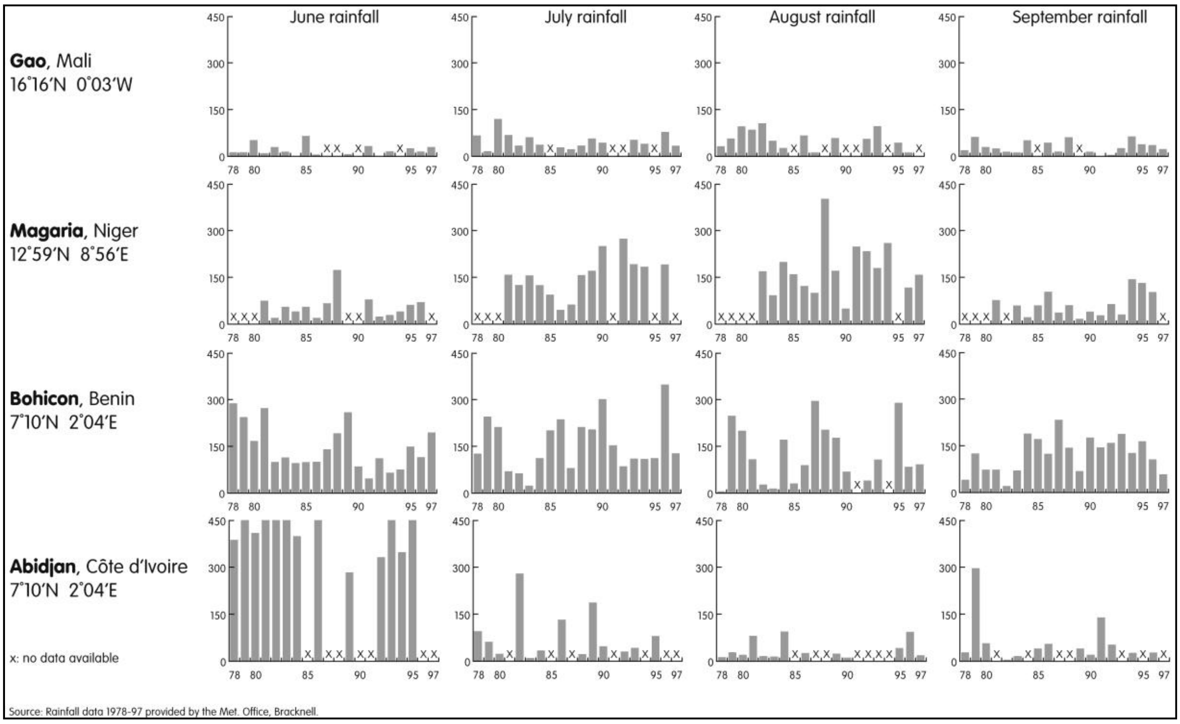

Figure 3.4 a) Variations in monthly June-September rainfall at four stations in West Africa (1978-1997).
Source: Baker (2000).

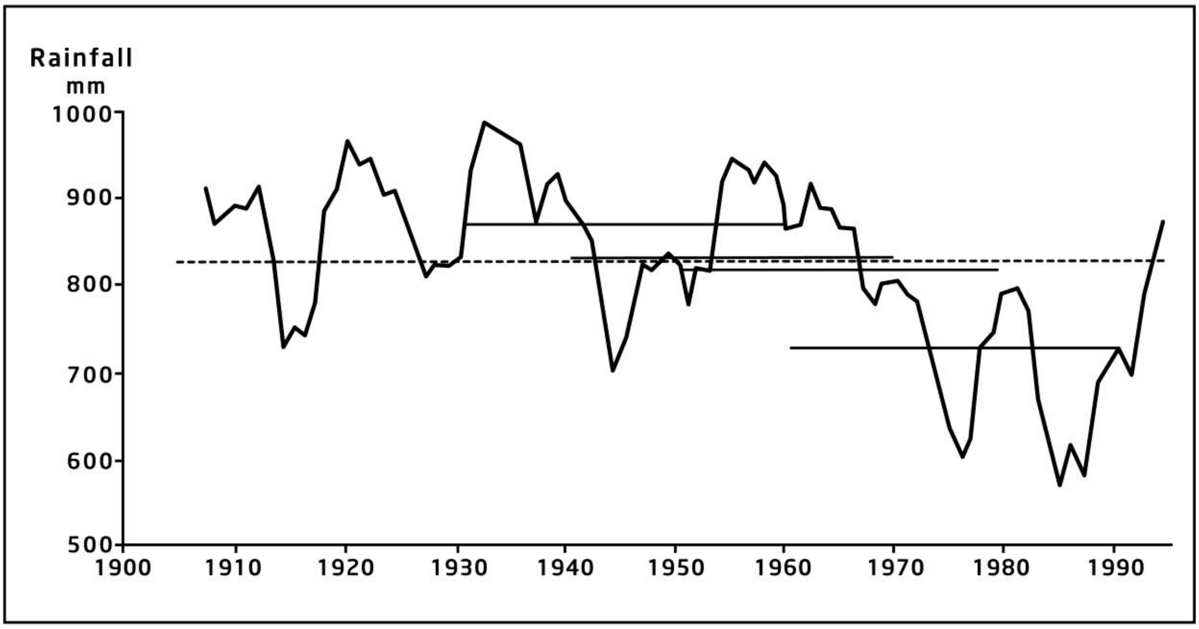

Figure 3.4 b) Annual rainfall at Kano, Nigeria from 1905 to 1992 (solid lines indicate five year running means for the periods they cover, the dotted line indicates the 1900- 2000 mean).
Source: Mortimore (1998b).
Figure 3.4 Inter- and intra-annual variation in West African rainfall.

Figures 3.2, 3.4 and 3.6 demonstrate how natural capital is unevenly distributed within the West African savanna agroecosystem. This makes smallholders' choice of soil input crucial, as moisture as well as nutrient availability is necessary but problematic. Building up SOM levels with organic soil amendments improves soil structure and water retention in the long term, but in the short term large quantities of nutrients are most easily added as expensive inorganic chemicals. Hence the ongoing debate over the relative importance of organic and inorganic fertilisers which, as it has developed, has engendered paradigm shifts within the SFM literature. These will be explored in more detail in section 3.4, but suffice it to mention here that a key element of this debate has been the gradual recognition that agroecological factors such as precipitation and soil interact with the socioeconomic environment.

The agroecology of the West African precipitation regime and its regional soil characteristics have not changed over a human timescale. However, demographic and environmental change have affected the way people work within it and therefore the relative influence it has in determining appropriate capital management strategies. Population growth and urbanisation in the peri-urban study area have put pressure on the limited resource base and simultaneously created opportunities in new economic activities. People have responded to these changes with various strategies that comprise the socioeconomic background to the SFM options to be detailed shortly.

3.3 Livelihood strategies

In response to land shortage Dagomba farmers have adopted off-farm and on-farm diversification (Bryceson and Jamal 1997; Ellis 2000) as well as intensification (Prothero 1957; Boserup 1965; Mortimore 1998a).

3.3.1 Diversification

People diversify either in order to accumulate or simply in order to survive (Tacoli 2002). Those already owning means of production are more likely to successfully accumulate further individual capital than those who need to diversify to survive. In Dagbon, even the most visible off-farm diversification strategy, circular migration of young women to Southern Ghana as 'k*ayayei*' (head porters) (Opare 2003) has a minimum capital requirement: human capital for strength, knowledge of routes and language and personal financial capital for the lorry fare. Other common diversification activities that do not involve migration include petty trading, for example of phone units and petrol, and on-farm diversification into alternative cash crops like cotton, tobacco and dry season irrigated vegetables. Many have become tailors, carpenters and masons and such professional training requires time investment. Diversification is not new, but the numbers of people involved, the distances they migrate, the range of activities they pursue and the degree of flexibility of different strategies within an individual's livelihood has changed over time. People also draw upon multiple systems to access the capital they need for each diversification strategy: for *kayayei*, the state's physical capital provides the roads that facilitate migration and, once in the cities, traditional social capital bonds have a role to play as they form alliances with their tribespeople, acquaintances and kin. The Market creates most of the opportunities for the forms of diversification listed above.

3.3.2 Intensification

However, most Dagomba smallholders lack the necessary capital for diversification on a large scale, so they must intensify instead or as well (Carswell 1997). This is particularly true for those landlords who have a social responsibility to grow maize for the household's consumption and for the majority who lack irrigation water for dry season on-farm diversification. Intensification is defined as anything that increases yield on a given area, including new varieties and species of crops, additional labour and soil inputs. As well as individuals' traditional subsistence responsibilities, commercialisation can also be a driving force: much on-farm diversification involves intensification as farmers grow new cash crops like vegetables and even produce maize for the market under outgrower or fertiliser input schemes (Guyver and MacCarthy 2011). Again, those individuals with access to the means of production are most likely to successfully accumulate capital through intensification. The patterns of mutual facilitation between different systems of access to capital detailed in Chapter two are therefore relevant to SFM, a mode of intensification.

3.4 Paradigms of West African environmentalism and Soil Fertility Management

Applied science is rarely objective: the paradigms by which systems of capital use are informed have influenced the study of Soil Fertility Management. SFM research itself has passed through different paradigms in which different conceptualisations of subject specific processes have influenced the recommendations that scientists have made; this section details that process. Since the 1960s, there have been four broad paradigms of tropical Soil Fertility Management (Bationo 2009; Sanginga and Woomer 2009; Vanlauwe 2009). In the 1960s, external inputs were considered essential, a view entirely overturned by the 1980s swing to the Low External Input Sustainable Agriculture (LEISA) approach. In 1994 Sanchez's 'second paradigm' described a 'middle way', emphasising 'minimal' and 'efficient' use of external inputs. The current Integrated Soil Fertility Management (ISFM) orthodoxy recognises how SFM links to other livelihood concerns such as the market and slightly shifts the emphasis back to inorganic fertilisers with the idea that external inputs should be 'optimized ' rather than minimised.

Table 3.1 Soil fertility management paradigms.
Adapted from Sanginga and Woomer (2009).

Period	Paradigm	Role of inorganics	Role of organics	Critique
1960s - 70s	External inorganic input	Provide nutrients to sustain yield	Minimal	Constrained by supply infrastructure and policy
1980s	Organic input/ LEISA	Minimal	Main nutrient and substrate source	Difficulty accessing organic resources
1990s	Second paradigm	Provides nutrients	Entry point, supplying functions other than nutrient release	Difficulty accessing organic resources
2000s	ISFM	Entry point, supplying nutrients and higher volume of crop residues	Limited by social and economic factors	

Recognising that tropical soil science sits within and next to other concerns, these four SFM paradigms will be followed through four successive historical approaches to general environmentalism and agricultural policy relevant to post-colonial West Africa. Organising the examination in this way aims not only to situate tropical SFM within its wider historical, political, social and economic context but also to show how the contentious ideas that have shaped its development can be traced at least as far back as the colonial era. The first three schools of thought influencing thinking on West African soils used nutrient balancing, political ecology and participatory approaches. The final part of section 3.4 will examine the more recent literature specifically dedicated to the study of tropical SFM and through this will demonstrate the distinction between the 'second' and 'integrated' SFM paradigms.

The analysis will consider the relationship of these schools of thought to the paradigms of capital use described in Chapter two and the different research methods favoured by each school will be assessed. The section will also provide a platform from which to evaluate the importance of SOM and link it to a critical management consideration, crop livestock interactions.

3.4.1 Nutrient balances

Concerns over environmental 'degradation' in West Africa stem from the colonial era (Fairhead and Leach 1995; Basset and Zueli 2000; Fairhead and Scoones 2005; Koning and Smaling 2005; Laris and Wardell 2006) and that legacy is still evident in the nutrient balance approach. Issues of data collection and scale, as well as the conceptualisation of nutrients as capital, make this approach problematic.

Colonial authors proclaimed that stocks of nutrients in African savanna soils were diminishing, with dire consequences for pastoralism and agriculture. Those who originally constructed this narrative used mainly qualitative evidence and misunderstood the non-equilibrium savanna ecology. The value of recommendations was limited by the paucity of reliable quantitative data and the lack of a baseline with which to compare it. In West Africa deforestation and desertification were the major concerns of colonial botanists and foresters like Andre Aubreville; in southern Africa the focus was on herd size ('overstocking'), rangeland 'degradation', erosion and to a lesser extent on declining yields. Observing unproductive patches of range and cropland within the heterogenous savanna mosaic, colonial administrators and scientists interpreted them as symptomatic of impending density-dependent degradation of the climax community, rather than as patches of disturbance in a polyclimax. Such concern over nutrient depletion and land 'degradation' has continued almost unchallenged until relatively recently, despite gradual parallel recognition of the nutrient cycling that occurs during shifting cultivation (Nye and Greenland 1960; Vine 1968) and the importance of non-equilibrium ecology in the savanna. These concerns formed the basis for the 1960s and 1970s 'first paradigm' of SFM (Bationo 2009; Vanlauwe 2009). This emphasised the importance of external inputs and informed the Green Revolution (GR). As mentioned, the increases in yield that this technological fix generated in Asia were not, however, replicated in Africa. Nevertheless, these ideas prevailed. Although other paradigms accumulated alongside it, the external input paradigm held sway to some extent until relatively recently, despite the extensive critique over the GR's inequitable effects, e.g. from Cleaver (1972), Ladejinsky (1973) and Shiva (1991). The nutrient balance approach was most notoriously applied to the African continent by Stoorvogel and Smaling in their 1990 FAO model (Stoorvogel *et al.* 1993). This extrapolated data collected at a local scale to the whole of West Africa, bringing to the forefront the debate over whether the nutrient balance approach was in fact helpful. Figure 3.5 shows how Stoorvogel *et al.*'s model of soil fertility envisages the soil as a stock of nutrients with five inputs and five outputs, which must 'balance' for the system to remain in a sustainable equilibrium.

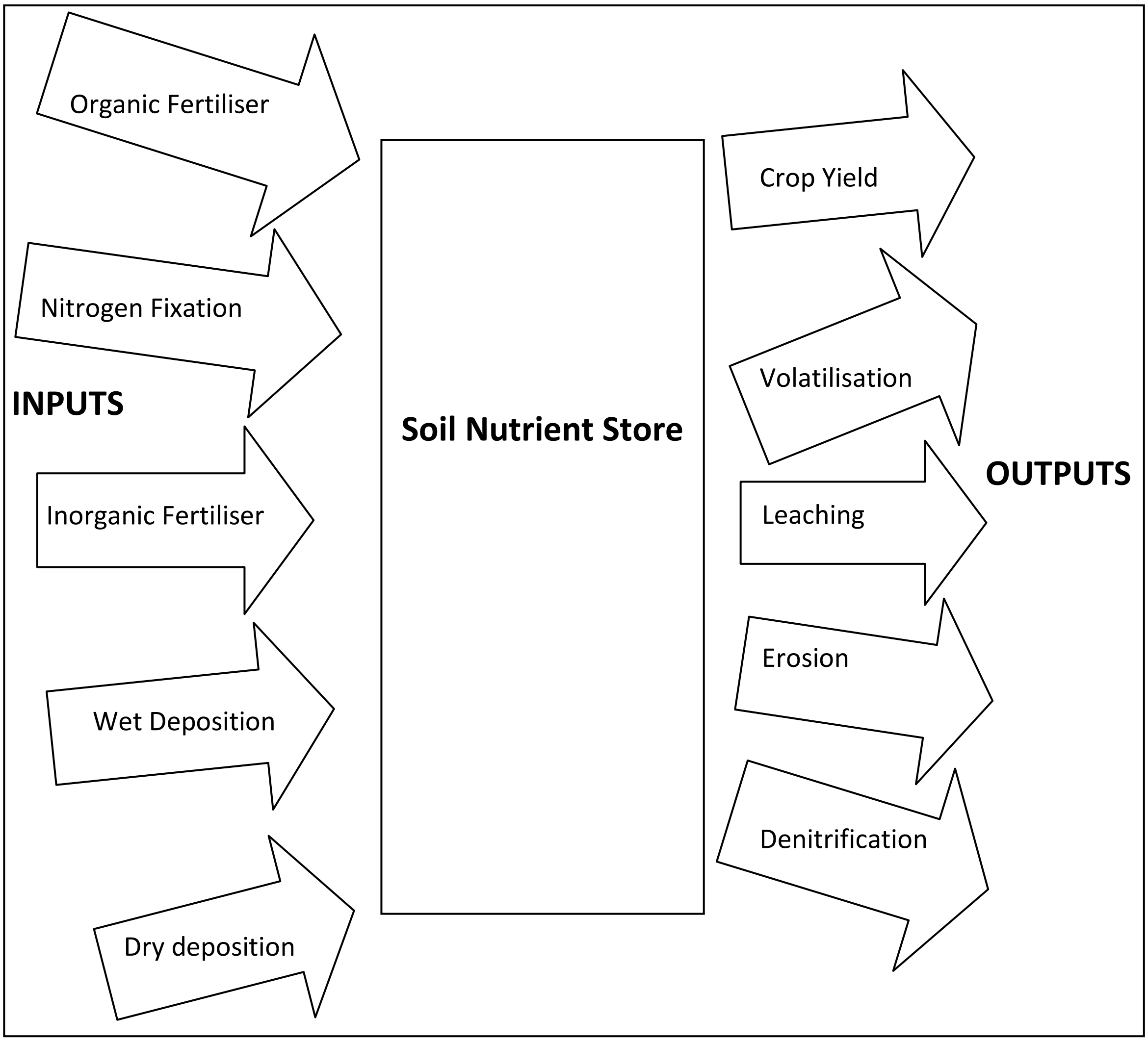

Figure 3.5 The nutrient balance concept.
Adapted from Stoorvogel *et al*.(1993).

It is now widely recognised that despite their simplicity, which make them attractive to policy makers (Scoones and Toulmin 1998), nutrient balances can only be used as one in a set of nutrient analysis tools; even Smaling *et al*. (1996) agreed that the 1990 model extrapolated too much. The main issues of relevance here are to do with the availability of data and the scale of analysis.

Data on many of the inputs and outputs are limited (Manlay *et al.* 2002; Roy *et al.* 2003). It is hard to quantify wet and dry deposition, N fixation, leaching, erosion, volatilisation and denitrification (Smaling *et al.* 1996; Bationo *et al.* 1998; Warren *et al.* 2001). Some authors, such as Pol and Traore (1993), are therefore obliged to use values from the literature rather than direct measurements of these fluxes from their study sites.

Most crucially, nutrient balances extrapolate poorly to the large scale (Roy *et al.* 2003). The scale of analysis determines whether the balance will be positive or negative (Krogh 1997; de Ridder *et al.* 2004). Manlay *et al*.(2004) calculated nutrient balances at field and village scale in Senegal and found concentric rings of fertility around settlements, in a pattern common throughout agricultural landscapes. Farmers transfer nutrients from the less fertile outlying bush and savanna rings to the nutrient rich compound ring, with the result that when the village was examined as a whole system the nutrient budget was more balanced. Krogh (1997) made a similar analysis in Burkina Faso and concluded that the village scale was appropriate because it related to the scale of agricultural decision making in that community - in effect framing the village as a closed system. However Scoones and Toulmin (1998) consider that as managers make decisions at the field scale this is the appropriate unit for academic analysis, with the additional benefit of facilitating farmer participation. Evidently the farm decision-making system determines the appropriate scale of examination. Other sources of small scale spatial heterogeneity in the savanna (Mugwira and Nyamangara 1998) are masked when nutrient balances are scaled up. Key resource patches like wetlands (Illius and O'Connor 1999), woodlands (Elliott and Campbell 2002), burn sites (Laris 2005; Oyama and Kondo 2007) and abandoned settlements (Fairhead and Scoones 2005) are not reflected in extrapolations of local data to the landscape scale. This is of particular relevance in the patchy mosaic of the non-equilibrium savanna ecosystem. Figure 3.6 shows the varying spatial resolution of three soil maps and figure 3.7 shows soil nutrient balance maps for Africa and Ghana based on Stoorvogel and Smaling's (1990) study and Lesschen *et al.'s* 2003 FAO study. It follows that policies would differ depending on whether policy makers choose to use smaller or larger scale data.

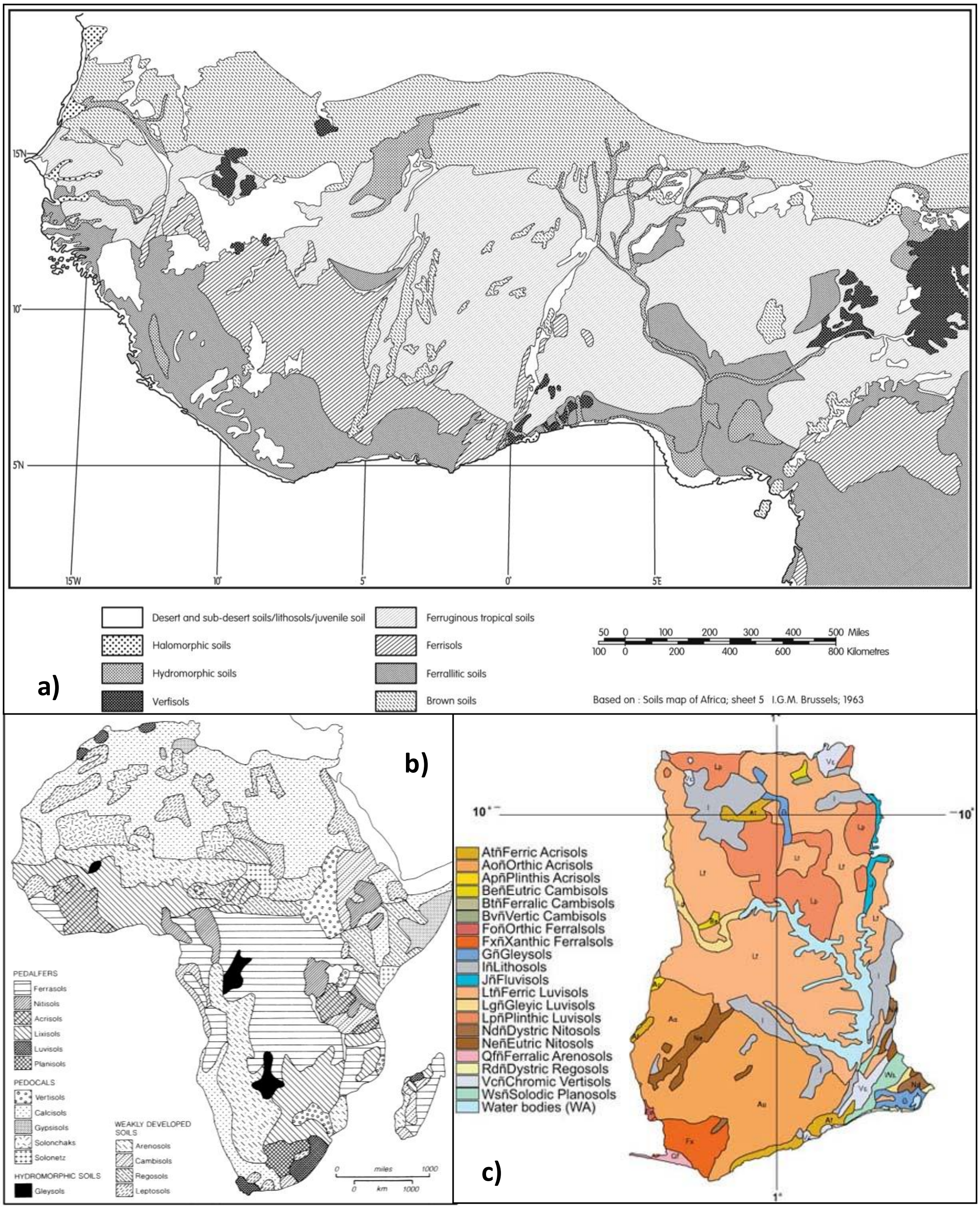

Figure 3.6 Soil maps at different scales.
Sources: a) Morgan and Pugh (1969) b) Areola (1996) c) FAO (2005).

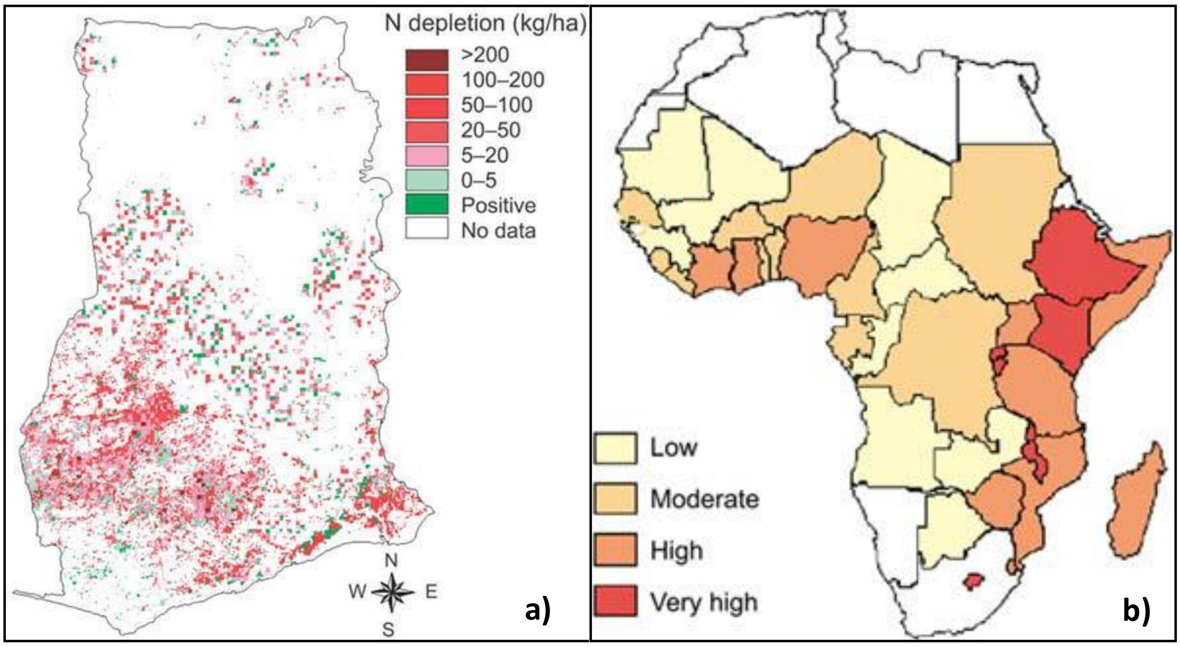

Figure 3.7 Soil nutrient balance maps at different scales.
Sources: a) Lesschen *et al.* (2003) b) Stoorvogel and Smaling (1990) in Roy *et al.* (2003)

Temporal scales are equally important. Nutrients are released from OM over the space of several years and from inorganic fertilisers generally in a single season, so applying nutrient balances without a timescale is less meaningful (Shepherd *et al.* 1995; Harris 1998; Scoones and Toulmin 1998). Build-up of OM and development of soil structure may take up to 30 years, dependent upon site (Nye and Greenland 1960; Ouedraogo *et al.* 2001) so Bationo and Mokwunye (1991b) considered that five years was not enough time in which to observe changes in savanna SOM and structure. Data from studies analysing soil over one year only, as was the constraint on this thesis, are therefore more likely to reflect past management practices than recent ones. Many authors have accordingly adopted a site history approach (Scoones and Toulmin 1995; Osbahr and Allan 2003), which may be more relevant than using nutrient balances when long-term studies are impracticable. The catastrophic effects predicted from the earliest nutrient balance studies have not come to pass, indicating that the methodological problems of quantification and scale overemphasised outflows relative to inputs.

Despite these caveats, Stoorvogel and Smaling (1990) are often still cited as proving that soil degradation and 'mining' is occurring in West Africa by authors like Bationo *et al*. (2007), Bationo *et al.* (1998), Abunyewa *et al.* (2007), Sanchez *et al.* (1996) and Rockstrom *et al*. (2010) . References to low soil fertility and soil depletion in 'Africa' as a whole may also be found, for example , in Quifiones *et al.* (1997), Mohamed Saleem (1998) and Masvaya *et al.* (2010).

As the equilibrial nutrient balance approach conceptualises soil nutrients as a fixed stock of capital, it implies that an additional external nutrient source is required to balance those removed in crops. This is true if annual cropping is to take place in the savanna, as the natural rate of regeneration cannot keep pace with annual removal. Yet it is interesting to note the misapplication of the words '*re*capitalising' (Breman *et al.* 2001) and '*re*plenishing' (Vanlauwe *et al.* 2001b) to this intensification process. The highly weathered West African soils have always had low fertility on a human timescale (Kowal and Kassam 1978; Fairhead and Scoones 2005), capable only of supporting cropping as part of a system of shifting or rotated cultivation. Intensification to facilitate annual cropping is in a sense 'capitalising' the soil to this level for the first time (Powell *et al.* 1996).

Most analysts seem content with the conceptualisation of nutrients as capital in the same way that social capital has been described in economic terms. This approach suggests that the nutrients supplied from organic and inorganic fertilisers are interchangeable, based on the evidence that incorporation of organic matter can reduce the amount of fertiliser required to produce maximum yield (Bayorbor *et al.* 2006) and on comparisons of fertiliser and manure cost (Omamo *et al.* 2002). Yet such a description to some extent misrepresents the function and behaviour of nutrients: inorganic and organic nutrients are not fungible. In an ecosystem nutrients do not just flow in and out of biotic and abiotic components but exist in the soil phase in different, more and less available pools. Nitrogen in particular is unlikely to be held like money in a stationary stock as so many of its forms are soluble and biologically transformed; N mobility is therefore an especially important consideration in the sandy, low organic matter soils of the savanna. Phosphorous may be more or less available depending upon whether it is sorbed to an edge or an interlayer site on a clay. Interactions between nutrients, OM, metals, aggregates and other components alter nutrients' behaviour, and pulsed events of high precipitation and fire that characterise the non-equilibrium savanna ecology contribute toward their more variable, irregular flow across space and time in this biome. The form as well as the quantity of the supplied nutrients therefore affects their behaviour and residence time.

Nonetheless, the equilibrium conceptualisation of soil nutrient stocks held in a steady state led many authors to advocate substantial increases in inorganic fertiliser use (McIntire and Powell 1995; Quifiones *et al.* 1997). These ideas have been translated into policy, for example in The World Bank Soil Fertility Initiative which suggests a role for national governments alongside the private sector in promoting fertilisers (Breman *et al.* 2001) just as its National Environmental Action Plans became country policy under SAPs (Basset and Zueli 2000). This stance considers that Transfer of Technology through the Training and Visit extension method is the most appropriate extension strategy as it can encourage uptake of technological solutions like inorganic fertilisers. An emphasis upon technological solutions that can be bought with financial capital borrows from the weak sustainability idea that a personal or state supply of money can replace nutrient capital.

Although the two concepts do not perfectly superimpose, it can be seen that there are parallels between the nutrient cycling school of thought and the capitalist paradigm outlined in Chapter two (Fairhead and Scoones 2005). The balancing approach conceptualises nutrients as liquid assets that may be accumulated to 'capitalise' units of soil. The management techniques that translate this SFM paradigm into practice similarly resonate with a commercial agricultural system, as financial capital from crop sales facilitates fertiliser purchase. There is, however, a role for the state within the nutrient balancing paradigm, as it may provide some of the capital necessary for external nutrient supply, most significantly with fertiliser subsidies. This was the approach taken by modernising newly independent African states, and recently returned to in the post-SAP era in many countries, including Ghana.

3.4.2 Political Ecology

The role of the state was further emphasised by political ecologists, writers who recognised the flaws in the purely technical and market-based nutrient balancing approach. Their response is indicative, as they identified that political and social considerations as well as available capital must be considered when assessing solutions to agricultural issues like SFM. Although this approach recognised the social, economic and political context of agriculture, its focus upon the importance of access to financial capital diverted attention from the importance of organic matter in savanna agrocecology and again demonstrates a lack of interdisciplinarity.

There were two major elements to the political ecologists' critique of the nutrient balance approach. Firstly, they identified the poor data base upon which it was founded, permitting adoption of an inappropriate Clementsian equilibrium concept of ecology. Although not many political ecologists tackled the technical numerical inaccuracies of nutrient balances, they did point out that many claims of 'degradation' were based on an ecology that emphasised the desirability of maximum yields and livestock weights. Indigenous concerns diverged from this: pastoralists' aims were risk reduction and herd recovery after drought (Abel and Blaikie 1989; Whiteside 1998) and arable farmers often aimed to optimise output from productive niche spaces when drought or pests lowered yields elsewhere. These optimistic and opportunistic production strategies were shaped and defined by the variable and unpredictable agroecology of the non-equilibrium savanna environment (Harrison and Shackleton 1998; Illius and O'Connor 1999; Archer 2000).

Secondly, political ecologists considered that using physical data alone to show perceived 'degradation' in some areas masked the underlying political reasons for such changes. This argument was particularly relevant in southern African countries like Zimbabwe and South Africa where land cover change was due to state alienation of land from smallholders, forcing them to be concentrated onto the remaining parcels (Murray 1981; Nyamapfene 1989; Mather 1997; Scoones 1997). An argument more relevant in West Africa, with its lower incidence of land alienation and recorded forced labour, was that the true political reason for low yields was governments' failure to support farmers with the 'favourable policy environment' required to make their crops profitable (Bates

1981). Such an environment could be engendered through 'indirect investments', for example using price adjustments (De Jager 2005; Heerinck 2005; Koning and Smaling 2005; Mortimore and Harris 2005), generally preferred by more market-oriented commentators to the 'direct investment' of fertiliser subsidy (Shapiro and Sanders 1998). However, crucially, both these are manifestations of the state's financial capital, so political ecologists took the structural view that economic policy primarily determines the profitability and therefore the adoption of SFM strategies (Wiggins 2000). Indeed, much political ecological analysis focuses on the inequitable effects that arise when unfair policy allows powerful elites to alienate natural resources in order to accumulate wealth, often by manipulating markets (Verhoeven 2011). Authors like Basset and Zueli (2000) identified that this was based on a similar discourse to that promulgated to justify donor intervention in environmental management in West Africa (Basset and Zueli 2000).

Such political concerns do bear some relevance to the SFM scenario in Northern Ghana. The north of the country has been less developed since colonial times. Gold Coast colonists used anecdotal and qualitative data to claim that the then Northern Territories were inherently unproductive, justifying their focus upon the cocoa farms and goldmines in the South, and indeed there was a consequent migration of northern labour to these areas (Plange 1979; Cleveland 1991) as a response to economic opportunity (Sutton 1989). Nkrumah's post-independence programme of industrialisation did little for smallholders, who struggled to pay the taxes he used to fund it and benefitted little from nationalisation.

Understanding the historical political economy is essential for the analysis of the land disputes between kingdoms like Dagbon and the 'stateless' acephalous Northern peoples like the Konkomba (Weiss 2005), and there was a small amount of land alienation in Upper East region (Cleveland 1991), although inexplicably there does not seem to be any academic debate over the impact of the creation of Mole National Park in Northern Region (Mason 1993). However the policies that alienated huge tracts of land from the users in southern and eastern Africa did not occur here, and specifically this did not reduce fallows or prevent SOM establishment. The major reason for land shortage in contemporary Dagbon is land subdivision due to population growth and urbanization. An obvious focus for political ecologists examining SFM would be to analyse which parties would benefit from a tale of nutrient depletion, and although Fairhead and Scoones (2005), (authors more in the participatory camp) relate the nutrient balance approach to 'capitalist' agriculture none followed the argument to its conclusion by specifically identifying a fertiliser lobby. A political ecology standpoint ascribing political motives to the focus on land degradation is less relevant in this thesis.

There were also queries over the types of data political ecology used. Walker (2005), Simon (2008), and Vayda and Walters (1999) described concerns that as political ecology is primarily an analysis of the politics of resource struggles it bears little relationship to evidence-based 'ecology'. However, in West Africa, authors including Fairhead and Leach (1995), Elliot and Campbell (2002) and Bassett and Zueli (2000) made evidence-based political ecological assessments; they collected ecological data, primarily aerial photographs and transects, and used their findings to refute the dominant narrative of deforestation and desertification by reinterpreting wooded patches on the savanna–forest boundary as afforestation rather than Savanna encroachment. Similarly, Wardell *et al.* (2003) and Dahlberg (2000) used such data to illustrate that land cover change was related more to spatial boundaries of colonial labour reserves in the Upper East of Ghana and Botswana than contemporary population density. However, the literature on soil nutrient levels outside the deforestation or erosion contexts is scarce, partly because, like the colonists and early equilibrium ecologists, those few political ecologists examining soil fertility in West Africa have hitherto often been limited by a poor data base to possible reinterpretations of previous studies or historical anecdotal data.

Another linked concern relates to scale: considering the site specificity of soil-plant interactions in the heterogeneous West African savanna ecosystem, the policy-level approach espoused by many political ecologists also ignored the plant-nutrient interactions that occur at the scale of the farmers' field. This reinforces the conclusion that traditional political ecology is a framework less relevant to West African SFM. As it rightly emphasised the importance of economics and politics it could be perceived that it has something in common with ISFM, and the consideration of non-physical factors it engendered informs the valuable smaller scale participatory and ISFM studies to be examined in sections 3.4.4 and 3.4.5. However it was not sufficiently interdisciplinary as the focus on political and economic factors sometimes led it to emphasise policy-led financial capital-heavy solutions like fertiliser subsidy (Breman *et al.* 2001). This pays insufficient attention to agroecological factors, crucially the fact that most West African soils are poor in SOM and need organic matter to be added to create low risk agroecosystems with consistent annual yield. The importance of SOM is emerging as a central theme, although one neglected by the nutrient balance and political ecology approaches. This importance must be explained in more detail before proceeding to analyse the participatory and ISFM approaches to SFM research.

3.4.3 The importance of Soil Organic Matter

Explaining the paramount importance of SOM shows why colonial ecologists, their successors studying nutrient balances and subsequently some early political ecologists were ill-advised to promote the use of fertiliser alone as a panacea.

To begin, consider the difference between the non-equilibrium savanna pasture ecosystem and the artificially managed equilibrium agroecosystem. The former is characterised by unpredictable and variable quantities of rainfall, and disturbance by fire and herbivory prevents its stabilisation at a climax community on a human timescale. In contrast, the less risky (Upton 1987) sedentary agroecological system aims for an artificial climax community with a predictable annual biomass yield. To achieve this, farmers intensify their use of organic matter to maximise not only nutrient input but also water retention (Tivey 1990) and so reduce the likelihood of lower yields due to variable rainfall. It is true that fertiliser would help raise yields if it were constantly available. It may be a solution for wealthy farmers in rainy temperate climates, but not only the economic and political characteristics of the West African savanna but also its physical conditions make inorganic fertiliser use risky, primarily in terms of plant available moisture but also plant available nutrients.

There are few regional rainfall data published for the past 10 years, but Le Barbé *et al.* (2002) describe the dry period from 1971-1990 - the duration of their data set - as having 0.1-0.2 fewer rainfall events and 1-1.5 mm less precipitation per day than the previous 20 years. There is also recent anecdotal, and some published, evidence of a lengthening dry gap in the middle of the growing season in some localities (Le Barbé *et al.* 2002; Frappart *et al.* 2009), with attendant effects on maturing maize (Sivakumar 1992; Sultan *et al.* 2005). Although it is impossible to tell whether such a change is permanent it is significant in the farmer's lifespan (Baker 2000) and accentuates the risks associated with the variable savanna climate (Mortimore 1998b).

A primary function of SOM is to increase porosity, both within the humus structure and as a result of its ability to stabilise clay aggregates within the mineral fraction (Tiessen and Shang 1998). Critically, this porosity raises the soil's moisture retention capacity (Tivey 1990; Bationo and Mokwunye 1991b; Franke *et al.* 2004). The geologically old, intensely weathered, sandy soils of Northern Ghana (Fitzpatrick 1986; Breman *et al.* 2001; Braimoh and Vlek 2004) are inherently low in SOM (Bationo *et al.* 1998) and clay. Irvine and Ahn (1970) and Nye and Greenland (1960) theorised that as SOM mineralisation rate approaches formation or application rate, soils reach a stable maximum organic matter content; this process was documented on temperate research plots at Whichmore, New Zealand, Askov, Nederlands and Rothamsted, UK (Haynes and Naidu 1998). As OM mineralises rapidly in tropical climates (Morgan and Munton 1971) the natural maximum is about 1% in Northern Ghana (Adu 1995; Fosu 1999; Braimoh and Vlek 2004). Such low SOM concentrations in Dagbon mean water retention is low, whereas in this unpredictable climate it needs to be high to reduce risks to sedentary agriculture. Although Breman *et al*. (2001) consider nutrient supply to be more of a limiting factor than water supply above 400mm (Bationo and Mokwunye (1991a) and Penning de Vries and Djiteye (1992) cited in Osbahr and Allan (2003) both lower this to 250mm for 'West Africa') they overlook the seasonality of the monomodal climate and the fact that the unpredictability of precipitation is more of a significant risk factor than the total annual amount. The importance of water retention demonstrates the strong sustainability viewpoint that some ecosystem functions cannot be replaced by substituting inorganic for organic nutrient amendments.

After water retention, the second crucial function of SOM is nutrient storage and supply (Quifiones *et al.* 1997; Bationo *et al.* 1998). Both clays and SOM supply nutrient ions, primarily cations (including K^+ and NH_4^+) but also some anions (including NO_3^- and PO_4^{3-}) made available on charged edge and interlayer exchange sites. As nitrogen is supplied primarily by biological processes and in soluble forms, its availability in soil solution is of paramount importance, particularly for maize, the cob development of which depends upon nitrogen uptake (Binder *et al.* 2000; Scharf *et al.* 2002). The rapid mineralisation and subsequent leaching of nitrate at the onset of the rains in the savanna emphasises the importance of plant available moisture in controlling access to plant available nutrients. Recognising this, split application of nitrogenous fertiliser is often recommended to circumvent loss through leaching (Irvine and Ahn 1970; Shisanya *et al.* 2009).

Available P and cations, on the other hand, are primarily supplied by chemical interactions, predominantly from cation exchange sites on clays. The sandy savanna soils have low clay content: in Tolon-Kumbungu district, in which one of the study villages is located, Braimoh and Vlek (2004) found clay content between 0.72 and 23.6%. This is a relatively high maximum, but their low mean of 7.2% demonstrates the characteristic spatial heterogeneity of savanna soils - patches of high clay content and fertility are found within the predominant low fertility sands. Furthermore, the dominant clay in the West African tropics is kaolinite, one of the least nutrient retentive, contributing further to the low fertility of these soils (Fitzpatrick 1986). Whereas illite and montmorrilonite have two silicate to every aluminate layer, kaolinite has a 1silica:1aluminate structure. This means that there are fewer negatively charged cation exchange sites and a smaller interlayer space, so the anion exchange capacity is relatively higher (Pansu and Gautheyrou 2006). Phosphate ions are therefore more commonly adsorbed to clay layer edges in kaolinite and may more frequently combine with cations in solution. In addition phosphorous is locked into unavailable aluminium and iron phosphates and phosphate ions are only slowly available as they may sorb to iron and aluminium oxyhydroxides and sesquioxides (Brady and Buckman 1974). Those phosphate ions that do become available are mostly held by OM on charged edge sites ready to be dissolved into the soil solution. The low clay content and limited release of phosphorous and cations from these clays means that SOM is an important phosphorous source (Manlay *et al.* 2002). Therefore despite large slowly available or 'unavailable' stores of P held tightly within the mineral fraction, the amount of available P and cations is limited by low SOM levels, to the extent that it is often the limiting nutrient in savannas (Sanchez *et al.* 1996). Many authors thus recommend the addition of partially acidulated phosphate rock (largely apatite and phosphates of calcium) for example from Senegalese, Malian and Nigérian deposits (Bationo and Mokwunye 1991a; Breman *et al.* 2001). However SOM would still be required for retention of P, confirming that it is essential for availability of nutrients as well as moisture in savanna soils.

The slow release of nutrient ions from clays and organic matter is not altogether problematic. As noted above, the onset of the rains may cause biologically fixed nitrates to leach. This is less of a problem for phosphates and cations, as the slower rate at which they are made available and their lower solubility precludes much leaching loss. A limited amount of nitrate and ammonium may also be prevented from leaching if held on exchange sites (Buckman and Brady 1969; Smith and Atkinson 1975). Soil Organic Matter is therefore essential for the retention and timely release of plant available nutrients as well as moisture in savanna soils.

Historically, the development of SOM during fallowing sustained shifting cultivation. If land pressure leads to the decline of fallows, SOM inputs are necessary to replicate natural sources of available water and nutrients on a human timescale. The strong sustainability viewpoint, emphasising the conservation of a particular type of natural capital, i.e. SOM, and the functions it performs, could be seen as a challenge to the capital liquidity of the livelihoods model. However, the livelihoods model can be incorporated into strong sustainability if farmers substitute capitals to facilitate an agroecologically appropriate solution - here the conservation of SOM. Indeed, organic SFM methods use human, social and financial capitals to replace used natural capital, replenishing and even increasing SOM levels. Through misunderstanding or disregarding the importance of plant available moisture and timely release of nutrients in the savanna, both political ecologists and those using nutrient balances failed to account for the biome specific importance of SOM. As their diagnoses of the problem are inaccurate their suggested cure of inorganic fertiliser, whether through market mechanisms or subsidised state supply, is problematic.

3.4.4 Participation and LEISA

As well as ignoring the importance of plant available moisture and nutrients, the early political ecologists' focus on the flaws in the nutrient depletion scenario distracted somewhat from analysing the intensification occurring at the local scale.

Participatory authors took something valuable from political ecology in the realisation that environmental management decisions are not influenced solely by physical concerns. However they diverged from the macro-policy scale of the modernisation approaches that focused on providing capital to farmers through market and state structures. Working at a more local scale, part of the participatory approach was to analyse individual farmers' innovative approaches to intensification. This laid some of them open to the critique of apoliticism described in Chapter 2, although politically informed analyses of participation now abound (e.g. Crook and Sverrisson 2001; Webster 2002). This section demonstrates how it also enabled them to recognise the importance of spatial intensification patterns, crop-livestock integration and site heterogeneity as well as social factors, thereby contributing to the new SFM paradigm that succeeded the external input focused approach - Low External Input Sustainable Agriculture (LEISA).

Like political ecologists, participatory authors questioned the colonial tale of massive nutrient depletion and in their emphasis upon farmers' solutions built upon Boserup's (1965) theory of intensification. This describes how farmers respond to population pressure by innovating and intensifying production as land supply becomes limited. Many participatory studies use livelihoods approaches to examine exactly how farmers use the human, social and financial capital held by individuals and the community to respond to their changing environments and needs.

As an illustration of this approach, the livelihoods model can be used to describe how intensification happens in Dagbon, along the lines of De Ridder *et al.'s* (2004) Boserupian 'path of development'. In the past, pastoralists and shifting cultivators used the natural capital of the non-equilibrial savanna. As populations rose, arable farming encroached on pasture (Karbo and Agyare 2002), then became permanent, using personal and sometimes community human capital to farm millet and yam. Intensive manuring and composting now artificially replicate SOM formation in fallows. Ploughing means arable farmers buy cattle (Powell *et al.* 1996) and cropping eventually prevents extensive grazing, so herdspeople may become sedentary farmers. As the system integrates into the market, cash crops and tractors are adopted. If SOM declines, financial capital supports yields through fertilisers and irrigation and hires labour. Thus a situation of exploiting natural capital has shifted to a managed agroecosystem, where farmers use individual and sometimes state and community human, social and financial capitals to support consistent biomass production. Smaling and Dixon (2006), in common with participatory authors, state that farmers' capital endowments affect their abilities to implement these changing SFM strategies. They consider that lack of financial, physical and human capital most commonly constrains successful management, whereas social capital most often facilitates it. Scoones and Toulmin (1995) examine this in more detail with their model of how social capitals interact with physical capitals in soil nutrient cycling, emphasising that the available capital and appropriate solution will vary between sites.

Chapter two explained how participatory authors consider human and social capitals to be the most important. Knowledge of new techniques is important and social capital is essential to foster not only farmer-to-farmer learning but also the community organisation required to implement group activity. This emphasis on the capitals related to the community rather than to individuals or external actors sometimes leads participatory authors to emphasize the LEISA techniques that rely upon them. Thus, past participatory composting projects in the study sites have used human and social capital in knowledge sharing (Clottey *et al.* 2006). Similarly, Njuki *et al*. (2008) considered that bridging social capital enables farmers to use knowledge intensive SFM techniques. Authors sympathetic to LEISA for environmental reasons, like Conway (1997) and Pretty (1995; 2002), also echo this focus upon participatory methods. Environmental motivations differ from the primarily emancipatory aims of those who pioneered participation, but the holistic approach common to many such commentators means the ideas converge. Many environmentalists emphasising the importance of site appropriate 'sustainable' solutions thus decry the switch from strongly to weakly sustainable systems evident in de Ridder *et al.*'s (2004) 'path of development' as the monetisation of agriculture replaces organic fertilisers with inorganic chemicals. When the natural capital of SOM is no longer replaced, the critical ecosystem function of water availability is only possible if irrigation can also be afforded. This is rarely the case in Dagbon, as in the rest of SSA, so the low technology solution of OM incorporation is the next best option, invoking the efficiency argument for participation. LEISA techniques are therefore associated with participation as both encourage use of community scale human and social capital.

The participatory literature thus examines many of farmers' own old and new low capital SFM techniques recognising their differential adaptation to and use of heterogenous landscape features such as termite mounds (Osbahr and Allan 2003) and wetlands. Use of such features may alter how closely a farmer pursues an intensification strategy. In a biome as enormous as the West African Guinea savanna there are myriad ecological niches and adapted systems, many of which are documented in collections such as 'Farmer Innovation in Africa' (Reij and Waters-Bayer 2001), 'Sustaining the Soil' (Scoones *et al.* 1996), 'Agroecological Innovations' (Uphoff 2002) and the 'Farmer First' series (Chambers *et al.* 1989; Scoones *et al.* 1994). These collections include examples such as the Northern Ghanaian *yaba itgo* (Millar 2001) as well as the *wafipa* and *zai* mentioned in Chapter two. The emphasis on innovation is a useful entry point to the analysis of spatial patterns of intensification and the importance of crop-livestock interactions.

This theme of spatial intensification is central to the SFM literature and highlights particularly well the interplay between social and economic forces and physical soil characteristics. Ring patterns of fertility described in nutrient balance studies have already been mentioned. Yet such patterns were noted and linked to agricultural economics over 150 years earlier in 1826 by von Thunen (Grigg 1995) who described how transport costs mean application of inputs like manure is concentrated close to their source, the house and kraal, so higher value crops or those requiring external inputs are located here (Chisholm 1968; Upton 1973; Smaling and Dixon 2006; Vanlauwe and Giller 2006). This pattern has been observed across West Africa (Fortes *et al.* 1947; Prothero 1957; Norman 1978; Mortimore 1998b; Ouedraogo *et al.* 2001) and in Dagbon manifests itself with cereals, especially the nutrient-hungry maize, concentrated around the homestead and legumes mostly located in bush farms (Sauerborn *et al.* 2003). Analysis of such spatial intensification highlights how livestock transfer nutrients from pasture to arable land (Powell *et al.* 1996). Even in the pastureless Nigerian Kano close settled zone, animals transfer nutrients from crop residues or browse in the bush zone and deposit it in the compound zone (Harris and Yusuf 2001). Extensive grazing is often inadequate as livestock will deposit insufficient nutrients on their owners fields, so authors like Bationo *et al*. (2007) favour instead a semi-intensive system of Crop-Livestock Integration (CLI) involving combining manure collected from stall-fed animals with crop residues before incorporating it into the soil.

Socioeconomic concerns are central to this practice, considering the financial and social costs and advantages of livestock (Powell and Williams 1993; Cochrane *et al.* 2005). Manure quality varies and as farmers have differential access to livestock (Quansah *et al.* 2001), determined by their socioeconomic characteristics, this affects how effectively they can use manure. Suffice it to note here that innovative farmers may target different manures to crops with varying nutrient requirements: leaf vegetables, for example, appreciate the high N content of poultry manure (Harris and Yusuf 2001). Consideration of such personal social factors is a distinguishing feature of the participatory approach. Such a small scale approach addresses the realities that political ecology and nutrient balances neglected, but has prompted critique that participatory authors should be careful not to extrapolate positive examples of smallholder survival to the whole of West Africa, thereby ignoring the macropolitical context.

Another relevant criticism is common to participation and political ecology - both are constrained by a poor data base on many of the factors they wish to assess, especially regarding quantitative data. Despite recognising the importance of farmer innovation, social factors and site specificity, many participatory authors are less rigorously quantitative than those using nutrient balances, often relying more on farmers' perceptions and explanations. For example, Fairhead and Scoones (2005) take a case study approach in their description of the fertile characteristics of soil around abandoned settlements and improved forest fallows, meaning there are no chemical descriptions of the sites under scrutiny. Onduru and Du Preez (2008) analysed farmers' perceptions of soil fertility and yield decline using interviews, but presented these perceptions as fact. Similarly Adjei-Nsiah *et al*. (2008), in an otherwise extremely rigorous study, like Batterbury (2001) in his political ecology of soil erosion, base their soil characterisation upon farmers' own characterisation and observing soil colour without using a Munsell chart. Fairhead and Scoones (2005) themselves point out that the epistemology of nutrient balance approaches, informed by a capitalist framework, coloured the perception of the results, and the same applies to their own work. Their valorisation of 'moral and social' values rather than economic or nutrient balances risks being overly affected by their own opinion. Qualitative data are more easily subject to multiple interpretations informed by farmers' and researchers' perception, and so are not as objective as ecological statistics. It is, however, true that data are scarce and therefore participatory as well as political ecology authors must often make do with what little there is (Gyasi *et al.* 1995). Historic performance indicators and farmers' site-specific, subjective assessments of soil characteristics are certainly well suited to livelihoods analysis, so cannot be rejected just for being insufficiently quantitative. In this situation the rigorous triangulation many participatory authors do perform is the only solution, and participatory authors rightly point out that physical data can only be explained and set in context with qualitative interview data. Ouédraogo *et al.* (2001) and de Jager *et al.* (2004), for example, combine participatory interviews with quantification of soil nutrient levels.

Another solution is use of detailed measurements meaningful to farmers such as weight as well as head of farmers' cattle, varieties as well as species of their crops, size of their fields, quality of the yield and type of rain. There are as many problems with these constructed data as there are with the extrapolation of small scale nutrient balances, so participatory studies must be especially careful to scrutinise and evaluate how their methodologies affect the results.

3.4.5 Soil Fertility Management literature

As a specific literature has developed around SFM, analysts have realised that SOM is vital and Integrated Soil Fertility Management (ISFM) has consequently become the dominant paradigm and management technique (Bationo *et al.* 1998).

In the 1980s acknowledgement of the high labour requirements of organic techniques and the low availability of organic residues led scientists studying tropical SFM to move away from LEISA. In 1994 Pedro Sanchez, cited in Vanlauwe (2009), formulated the second paradigm of SFM, stating that its ideology was to:

> rely more on biological processes by adapting germplasm to adverse soil conditions, enhancing soil biological activity and optimizing nutrient cycling to minimize external inputs and maximize the efficiency of their use.

This recognised the difficulty of using solely organic or inorganic inputs, but also the synergies and benefits that could be derived from their combined application. This will be explored in more depth in section 3.5. The interdisciplinary second paradigm considers physical, chemical, biological, social and economic factors, and most authors, including those who favour a sustainable viewpoint, now accept this idea of combined application to some extent (Fonte *et al.* 2012). Since the 1990s the 'second paradigm' has transformed further into the 'ISFM paradigm' Bationo (2009), defined by Vanlauwe *et al.* (2010a) as:

> a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients.

Like the second paradigm, ISFM advocates the combined application of inorganic and organic nutrients, but two linked elements of this new paradigm differentiate it from its predecessor. Firstly, ISFM makes the interdisciplinary approach explicit, recognizing 'the important role of social, cultural and economic processes' (Vanlauwe 2009, p.28). Secondly, as there is no longer an emphasis upon the 'minimal' use of external inputs there is a more positive perception of inorganic fertilisers, explicitly named as one of the sources of external nutrients as the rhetoric shifts away from applying minimal quantities to their 'optimum management' (Vanlauwe 2009, p.30). Inorganic fertiliser use necessitates cash transactions, so market integration is encouraged (Vanlauwe *et al.* 2010a) to enable farmers to generate the funds to purchase fertilisers and to increase demand for them (Reardon *et al.* 1999). Erenstein (2006) emphasises that intensification is more profitable when there is market access. Backwards and forwards market linkages reinforce each other, reducing farmers' transaction costs for both selling produce and buying fertiliser. Heerinck (2005), Place *et al.* (2003) and Crawford *et al*. (2003) describe how low market integration and low output prices discourage investment in land and how fertiliser use responds to improved crop prices. ISFM thus leans more towards market capitalism than the second paradigm, promoting an idea of commercial farmers using external additions of inorganic as well as organic fertiliser. However, the consensus is that in contrast to a pure market mechanism, government has a role to play, usually by encouraging the 'enabling environment' and occasionally through more direct mechanisms such as stabilising prices within emerging markets. The latter is particularly pertinent considering the variability of agricultural prices in SSA (Gabre-Medhin *et al.* 2003).

In fact, ISFM incorporates elements of each of the main approaches to understanding soil fertility - nutrient cycling, political ecology, LEISA and participation - and thereby involves coproduction as it embraces aspects of statist, participatory and capitalist ideologies.

The position of the Alliance for a Green Revolution for Africa (AGRA) is illustrative. The former vice president, Akinwumi Adesina, reflected the organisation's more political approach in his 2009 address to the United Nations Conference on Trade and Development. He sets out AGRA's support for tenets of structural functionalism, increased subsidy and government support for farmers, lauding the example of Malawis and Tanzania's most recent iterations of policies on fertilizer subsidies. Simultaneously, in agreement with authors like Sanginga *et al*. (2007), he emphasizes the importance of promoting farmers' entry into the capitalist marketplace. Adesina again finds a political solution to this, advocating the removal of international trade barriers on regional African markets and considers this should occur alongside state partnership with 'farmers' organizations and civil society', ideas participatory in origin but since adopted by the neo-liberal paradigm.

As the SFM literature has developed it has oscillated between the attention paid to external inputs by capitalist and statist approaches and the participatory and traditional focus on endogenous nutrient supply, gradually resolving around ISFM's general coproductive consensus on sustainable, combined application. There is still room for some manoeuvre between different practical positions within ISFM, as different stakeholders emphasise diverse ideologies over time. Currently the market approach probably dominates: despite receiving state and aid funding, notably from DfID, AGRA was instituted by private western, modernising and pro-capitalist funding bodies - the Rockefeller Foundation and the Bill and Melinda Gates foundations.

ISFM is based on empirical evidence. Authors from pro-ISFM organisations like the International Fertiliser Development Centre (IFDC) and local research centres have quantified soil physical and chemical properties and plant nutrient uptake throughout West Africa (Christianson *et al.* 1990; Bationo and Mokwunye 1991a; Braimoh and Vlek 2004; Abunyewa *et al.* 2007). Such local studies do frequently combine quantification with participatory methods (Warren *et al.* 2001; Clottey *et al.* 2006), to some extent incorporating and improving upon the methodologies associated with the nutrient balancing, political ecology and participatory approaches. Such efforts are necessary in Ghana considering the scarcity of soil data (Roy *et al.* 2003). As mentioned, a useful approach is to record 'performance indicators': income, returns to labour (de Jager *et al.* 2004), but primarily yield (Bationo and Mokwunye 1991a; Agyare *et al.* 2006). This is more important to farmers than nutrient balances, although a combination of data types will give more insight into the mechanisms through which SFM strategies influence output.

Bearing in mind the difficulties of accurately measuring all the nutrient cycling processes, field level data alone cannot give a satisfactory account of nutrient dynamics. However, establishing whether there are relationships between yield and nutrient levels, as well as other inputs like labour, will indicate the determinants of productivity and the mechanisms through which nutrient cycling affects it. Such field level data, often measuring heterogeneity at the smallest scale, have been collected in Dagbon as well as elsewhere in West Africa and this, perhaps more than any other body of work, illustrates the site-specific advantages and disadvantages of various SFM techniques. A cautionary note should be sounded - despite the stated interdisciplinarity of the ISFM paradigm and the integrated participatory and physical approach of authors like De Jager *et al*. (2001) a divide between human and physical approaches is still occasionally evident. Some academic work, as well as practice, still fails to take account of such important socio-economic factors as: conflicting demands for crop residues, cash availability, labour availability (Bayorbor *et al.* 2006), labour opportunity cost (Schlecht *et al.* 2006), accessibility of markets for surplus (Nederlof and Dangbegnon 2007) and farmers' ability to afford fertilisers (Bationo and Mokwunye 1991b). These, as well as the crucial significance of variable rainfall, must be considered by any credible research. The challenge now is to record detailed data with natural and human science, qualitative and quantitative methodologies, and synthesise them in context-specific holistic analysis. This thesis undertakes that task.

Those advocating different SFM solutions propose implementing different systems of capital use and development ideologies to different extents, and the idea of coproduction is increasingly common. Chapter six will consider which systems are implied by the insights of participating farmers. In this chapter it is now appropriate to draw out some statistics in a brief description of how SFM is currently practiced in Northern Ghana. The analysis will then move to a fuller exposition of current trends in intermediate transport.

3.5 SFM in Dagbon

Soil Organic Matter and fertility were traditionally regenerated through fallowing or shifting cultivation. With land now in short supply, farmers switch to other techniques. Traditional methods use natural and human capitals - crop residues are left on the fields and pollarding returns leaves to the soils. Crop rotation, especially with legumes, minimises the extreme nutrient depletion that results from continual cereal cropping. Although not strictly SFM techniques, weeding reduces competition for nutrients and ridging concentrates more fertile topsoil around the base of plants, working with the soil's existing fertility to maximise productivity. Physical capital is necessary for more recent LEISA techniques aiming to create SOM, a form of natural capital. Improved fallows and green manuring with crops like *Mucuna* and C*rotalaria* spp. fall into this category but are little practiced in the study area. More common is the incorporation of exogenous organic amendments. Of these, compost relies less on livestock ownership than manure, and incorporating household refuse or *'tampooli'* into the soil needs only access to a vehicle. Double ploughing is another more recently developed technique that requires access to bullocks. Fields are ploughed at the start of the rainy season, and once grass has regrown, two weeks to two months later, reploughed with cattle to incorporate it into the soil before sowing. Similarly, dynamic kraaling requires access to a herd of cattle that can be tethered at night on the field which is to be sown with cereals. Most capital intensive is the use of inorganic fertilisers, purchased with financial assets. The different capital requirements of these techniques means that if Dagomba farmers are to use them they must interact to varying extents with the systems of capital access and use detailed in Chapter two.

Up to date or indeed very detailed statistics are not available, but table 3.2 gives FAO data showing that although the uptake of 'fertiliser' in general was moderate in Northern Ghana compared to the rest of the country at the end of the 20th Century, government promotion of inorganic fertilisers mean they have been increasingly used.

Table 3.2 Average fertiliser use in Ghana by region (total kg fertiliser sold/ha).
Sources: Author's calculations derived from data on (1) Total fertilizer sales by region: MOFA (2003) cited in FAO (2005) and (2) land area: Ghana Statistical Service cited in Brinkhoff (2009)

Region	**1997**	**1998**	**1999**	**2000**	**2001**
Ashanti	2.12	1.60	0.83	1.66	3.05
Brong Ahafo	1.92	1.44	0.75	1.50	2.76
Central	1.66	1.25	0.65	1.30	2.39
Eastern	0.52	0.39	0.20	0.41	0.75
Greater Accra	3.81	2.87	1.49	2.98	5.48
Northern	***2.16***	***1.63***	***0.85***	***1.69***	***3.11***
Upper Regions	5.67	4.28	2.22	4.44	8.17
Volta	4.12	3.11	1.61	3.23	5.93
Western	0.14	0.11	0.06	0.11	0.20
Total Ghana	2.35	1.77	0.70	1.84	3.39

The same trend is illustrated in table 3.3. The data are not entirely credible: the very high 2010 MOP figures suggest there may be some misreporting and there is a note that in 2006 and 2007 NPK values are for '15-15-15 and other' although the 1997-2001 figures for NPK also exceed the data given for 15:15:15. However, these are the only data available, and they show that fertiliser use is rising. The data cannot, however, show the observation made in the field and corroborated by MOFA officers that compound maize fertiliser, 23N:10P:5K, is gaining in popularity upon 15:15:15.

Table 3.3 Apparent fertilizer consumption (import) by type.
Sources: (1) 1995-2001 data, MOFA (2003) cited in FAO (2005) and (2) 2002-2010 data, MOFA (2011a).

Year	15	Other CPD	Total CPD	SOA	Nitrate	Urea	MOP	TSP and SSP	Total
1995	9.3	0.0	9.3	0.9	/	4.3	/	/	24.8
1996	5.9	2.8	8.7	5.3	/	1.0	/	/	15.9
1997	19.2	17.9	37.1	10.7	/	1.9	5.5	/	56.2
1998	13.1	8.8	21.9	13.3	/	0.5	3.1	0.5	42.3
1999	3.2	0.4	3.6	4.8	/	/	8.1	3.5	22.0
2000	14.1	0.8	14.9	23.2	/	0.1	4.5	0.6	43.5
2001	31.8	17.5	49.3	22.6	/	2.5	4.1	0.7	80.8
2002	/	/	0.8	20.1	/	/	18.5	1.6	41.9
2003	/	/	18.9	25.7	/	0.5	23.4	/	92.8
2004	/	/	18.2	7.7	95.3	0.3	0.8	1.9	223.7
2005	/	/	39.0	15.0	0.2	4.5	1.0	1.0	91.3
2006	/	/	84.9	19.1	52.6	9.1	0.0	0.1	189.9
2007	/	/	87.4	17.5	52.8	5.0	0.1	0.5	189.6
2008	/	/	18.9	4.2	64.1	13.8	8.9	15.4	187.0
2009	/	/	197.6	4.6	0.1	25.0	15.0	66.5	335.2
2010	/	/	30.6	12.1	236.5	11.5	7216.1	52.1	7689.2

Notes: 15=15N:15P:15K, CPD=Compound, SOA=Sulphate of Ammonia, MOP=Muriate of Potash, TSP=Triple Super Phosphate, SSP=Single Super Phosphate, /=no data

These trends are national averages so will not be representative of Northern smallholders' use especially since the majority of fertiliser use in Ghana is probably still by southern plantation farmers producing export crops like cocoa and pineapples with specialist fertilisers (FAO 2005). Northern smallholders rely more heavily on the traditional compound and ammonia mixes for their cereal crops.

Columns 1-3 in Table 3.4 show that although up to 2002 Ghana had a fairly low rate of fertiliser application in comparison to some other African countries, rising Ghanaian application rates in contrast to falls elsewhere meant that by 2009 it was one of the leaders in fertiliser imports. It would be reasonable to conclude that this could be a result of the fertiliser subsidy the government instituted in 2008.

Table 3.4 Fertiliser application for selected countries and regions.
Sources: (1) Heisey and Mwangi (1996) calculated from FAO Agrostat PC Datafiles, (2) author's calculation from FAO Agrostat PC Datafiles accessed 2009 and (3) author's calculation from FAOSTAT accessed 2011.

Country/ region	Kg NPK applied/ha arable land 1989-93 mean (1)	Kg fertiliser consumption/ ha arable area 2002 (2)	Kg N, P_2O_5 and K_2O imported/ 1000 ha arable area 2009 (3)	Kg NPK/ha on area of maize receiving fertiliser (1)	Kg NPK/ha on total maize area (1)
Ghana	***2.2***	***7.4***	***11.9***	***52***	***14***
Cote d'Ivoire	12.3	38.9	15.9	103	5
Burkina Faso	/	0.4	9.1	/	3
Togo	/	6.8	3.3	63	10
Nigeria	13.7	5.2	2.1	176	113
Zimbabwe	52.0	34.1	28.0	122	55
Ethiopia	8.5	15.1	7.9	33	5
West Africa	/	6.3	3.3	/	/
Central Africa	/	2.9	2.3	/	/
West and Central Africa	7.8	/	/	/	/
East Africa	8.0	14.7	12.1	/	/
Southern Africa	17.5	60.7	44.5	/	/
Africa, including North Africa	/	20.9	10.0	96	33

Notes: /=no data

Use of inorganic fertilisers involves a complicated dilemma: their high financial cost at market rates seems to be offset by their positive short term effect on yield. However, there are some longer term agroecological drawbacks. It is helpful to detail those here, in order to facilitate comparison between these and the benefits of SOM build-up expounded in section 3.4.3.

Through additions of inorganic fertilisers, nitrate, ammonia, phosphate and potassium ions rapidly become available to plants directly through the soil solution, but the provision of cations and ammonia can result in acidification and associated metal toxicity as H^+ is displaced from exchange sites (de Ridder and van Keulen 1990; Pol and Traore 1993; Vanlauwe *et al.* 2001b). A point much emphasised in the recent ISFM literature, due to its focus upon improving the efficiency of external nutrient supply, is the importance of synchronising fertiliser application with demand: when nutrient ions are rapidly dissolved into the soil solution those not immediately taken up by plants may be lost via leaching. The most contentious potential drawback of sole fertiliser use concerns its relationship with OM. The importance of SOM in retaining plant available moisture and the nutrients dissolved within it has been described. Inorganic fertilisers do not directly establish SOM: using them alone without reincorporating crop residues means that organic matter is not necessarily returned to the soil. The soil's water retention capacity and its ability to retain nutrients both from fertiliser and biological and clay sources is thereby reduced as SOM degrades. Bationo and Mokwunye (1991b) consider that fertiliser indirectly facilitates higher organic matter content in soils through crop residue return and higher root densities. Haynes and Naidu (1998) reviewed evidence from long term field trials in Rothamsted, New Zealand and Netherlands showing this to be the case and describe how such additions of carbon stimulate soil microbial activity. However this effect relies on long-term, annual, chemical application and return of stover to the soil, something smallholder farmers are unable to achieve considering their financial and labour constraints. Indeed, clearing crop residues by burning, which requires little labour, means that although roots remain in the soil, above-ground biomass is not returned. Inorganic fertiliser cannot therefore indirectly raise SOM levels where burning takes place. So although Vanlauwe and Giller (2006, p.36) 'know of no evidence that fertilisers decrease….soil life or structure' it is more conceivable that under field conditions a short term supply of immediately accessible nutrients will facilitate microbial metabolism of existing SOM content raising the risk of water stress in subsequent years. If fertilisers cannot be supplied in consecutive seasons the same is true for nutrient supply. Sole inorganic fertiliser addition is therefore unlikely to replace the natural capital of SOM and its critical ecosystem functions. Inefficient uptake of macronutrients supplied by fertiliser may also result from other limiting conditions such as extreme pH or micronutrient limitation (de Ridder and van Keulen 1990) which, if it results from depletion of SOM as a result of long term cultivation under sole fertiliser application, is a positive feedback.

In addition to its interaction with organic matter, fertiliser use itself is risky under the variable savanna rainfall regime, as, in the absence of rain, fertilisers may corrode or 'burn' crops rather than stimulating growth.

Despite these longer term drawbacks, the fact remains that if fertiliser is supplied at high quantities, it can raise yields significantly in the first year of application, giving similar (Lanyasunya *et al.* 2006; Shisanya *et al.* 2009) or greater (Mathuva *et al.* 1998; Fandika *et al.* 2007) cereal yields than organic amendments alone. Despite some farmers' appreciation of the lower risks associated with organic amendments, many are drawn to inorganic fertiliser due to its potential to deliver good short term yield using less labour.

If this is so, why have inorganic fertilisers not been adopted as widely in SSA as they were in the Asian Green Revolution (Conway and Barbie 1988; Waithaka *et al.* 2007)? One answer lies in the fact that inorganic fertilisers are the only inputs to derive mostly from use of an individual's financial capital: most African smallholders are too poor to buy them. Table 3.5 shows the real costs of fertilisers in Ghana since subsidies were removed in 1987 (FAO 2005), adjusted for inflation. Changes in the base year of the Ghanaian Consumer Price Index, the 2008 currency redenomination and global food price spike and missing data mean the comparison is difficult, but relative fertiliser prices have continued to increase since 1988.

Table 3.5 Cost of fertilisers in Ghana. Sources: (1) FAO (2005) for 1988-2002 data, and (2) author's fieldwork for 2007-11 data. Adjusted for inflation with Ghanaian Consumer Price Index (Ghana Statistical Service 2012) (See appendix 1)

Year	**Real prices of fertilizer ('Pre-redenomination' GhC/100 tonnes adjusted for inflation using 1963 base rate CPI)**		
	15-15-15	**Urea**	**Ammonium Sulphate**
1988	5.51	No data	3.84
1993	7.30	3.61	6.70
1998	7.83	8.64	4.42
2002	11.24	11.74	9.33
2007 subsidised cost	1.60	1.48	1.60
2008	18.71	18.71	15.78
2008 subsidised cost	9.54	9.54	6.61
2009	16.01	16.01	No data
2009 subsidised cost	8.00	8.00	5.54
2010	13.34	No data	10.01
2010 subsidised cost	7.51	6.95	5.00
2011	15.57	14.18	11.12
2011 subsidised cost	7.67	7.42	6.39

Chapter six will detail some of the ways that coproduction may improve farmers' access to fertiliser.

In contrast to fertiliser, the low financial capital requirement of organic amendments is a major reason they are more appropriate in this environment, alongside their ability to return natural capital as SOM (Manlay *et al.* 2002). As well as improving the crucial water-holding capacity, chemical benefits include slower release of nutrients to the soil solution, improved use efficiency of inorganic nutrients and pH buffering. The supply of micronutrients and soluble C as well as macronutrients mobilises microbes, including those which may suppress weeds like the notorious maize parasite *Striga* (Quifiones *et al.* 1997; Sauerborn *et al.* 2003; Bationo *et al.* 2007) . Micronutrients and soluble C also mobilise macrofauna that in turn improve the physical properties of the soil through bioturbation and aggregation. As with inorganic fertilisers, it could seem that such a useful product should be universally adopted by farmers, but the drawbacks associated with different organic amendments include farmers' limited access to the necessary raw materials and the high labour costs of their conversion to a useful product.

In the study area, as in Kano close settled zone in Nigeria (Maconachie 2007), farmers apply a diverse range of organic amendments to their fields, including raw and rotted manure, mixtures of manure and organic residues, composted organic residues and household waste, each with different characteristics but generally termed '*kulum tam'* (literally 'fertiliser soil') by farmers. The quality of manure varies according to its animal source, in turn determined by farmers' wealth and its effect upon what type and how many animals they own. Table 3.6 indicates the range of possible nutrient values, illustrating that differences in breed, condition, diet and seasonality (Quansah *et al.* 2001) caused variation between the data of Shaffer and Walls (2005) from Carolina, USA, Harris and Yusuf (2001) from Northern Nigeria and SRI (1997; 1999) from Ghana.

Table 3.6 N, P and K content of various manures and amendments.
Sources: (1) Harris and Yusuf (2001), (2) authors conversion of data in lb/tone in Shaffer and Walls (2005), (3) SRI-CSIR (1997) cited in FAO (2005), (4) SRI-CSIR (1999) cited in FAO (2005)

Stock	**% N (dry weight)**	**% P_2O_5**	**% K_2O**	**Source**
Dairy	0.47	0.23	0.37	2
Beef	0.61	0.33	0.40	2
Cattle	1.20	0.17	0.11	3
Cattle, Upper East Region	1.34	0.33	2.00	4
Swine	0.56	0.42	0.00	2
Sheep	1.55	0.31	0.15	3
Sheep	0.94	0.43	0.86	2
Goat	0.99	0.55	1.07	2
Donkey	0.34	0.28	0.40	1
Horse	0.55	0.29	0.54	2
Poultry	2.20	1.80	1.10	3
Layer	1.21	0.97	0.53	2
Broiler	1.19	0.74	0.53	2
Small ruminant and straw	0.34	0.14	0.82	1
Small ruminant and cow	0.37	0.36	0.69	1
Cow and donkey	0.38	0.14	0.44	1
Rainy Season Manure	0.32	0.20	0.70	1
Dry Season Manure	0.25	0.20	0.83	1
Ash	0.21	0.28	1.66	1
Ash and Grass	0.17	0.18	0.97	1

Manure management also affects its quality in a more predictable and controllable way (Abunyewa *et al.* 2007). Storage period and surface, shelter and use of bedding to minimise ammonia leaching and volatilisation all have an effect. This variability in manure quality means application of laboratory values to field conditions is often less helpful. Heterogeneous application, ridging and topdressing also mean that the nutrients from manure are not evenly dispersed throughout or between fields (Harris and Yusuf 2001).

As well as direct application of manure, Dagomba farmers process it into compost by rotting it with crop residues in heaps or pits, and when faced with a dearth of labour and materials they apply household refuse. Categorisation into these three groups replicates the classifications they use to describe organic amendments.

Most farmers do follow the ISFM recommendation of combined application to some extent, largely because as they have insufficient capital to implement fully inorganic or organic strategies it increases the total amount of nutrients supplied. However, they also recognise the synergies between the different methods. These will be explained here, before summarising how the SFM literature demonstrates the importance of an integrated approach, which in turn implies the importance of intermediate transport.

Combined application has non-additive effects on the availability of organic and inorganic nutrients to plants as well the plant's ability to take them up. When applied together, organic and inorganic amendments may have synergistic or antagonistic interactions (Powell *et al.* 1996) depending on whether they are in physical contact. One categorization of these interactions is made by Vanlauwe *et al.*'s (2001b) direct and indirect hypotheses. The direct hypothesis considers interactions that transform N into more and less available forms, improving synchrony. Vanlauwe *et al.* (2002) give a microbially mediated example, where microorganisms temporarily immobilise the N that may otherwise be leached out as nitrate into their biomass, and release it slowly by mineralisation at periods of maximum plant nutrient demand. There are other chemical mechanisms that enhance nutrient use efficiency by improving synchrony, for example when inorganic species are sorbed to or complexed by organic molecules and subsequently released (Zech *et al.* 1997).

Vanlauwe *et al.*'s indirect hypothesis relates to organic matter alleviating limiting conditions by allowing plants to take up the macronutrients in inorganic fertilisers. De Ridder and van Keulen (1990) consider that when organic matter provides limiting micronutrient cations, crops can better take up N and P in fertiliser and it is this, rather than macronutrients held in the OM, that enhances yield. Vanlauwe *et al.* (2001a) conclude that as Sekou in Benin and Glidji in Togo were already sufficient in micronutrients, the water retention capacity of added SOM was the characteristic facilitating plant uptake of chemical macronutrients. This prevented the drought stress that reduced the yield when purely inorganic treatments were applied. De Ridder and van Keulen (1990) refute this, saying that the quantities of organic matter added are rarely enough to affect such structural properties of the soil. They consider that stimulation of the soil microbial community could be another mechanism by which organic fertilisers facilitate uptake of macronutrients provided by inorganic fertilisers.

Considering that mineral fertilisers, especially the compound formulas that dominate the Ghanaian market (tables 3.3 and 3.4), rarely provide the micronutrients that SOM contains, this property of SOM is likely to play a major role. Water retention capacity is a further common facilitatory characteristic in the rainfall limited savanna climate. ISFM proponents do consider the water retention properties of SOM important (Bationo *et al.* 2007; Hati *et al.* 2008). However, few authors note that these properties are more important in the monomodal savanna climate than the bimodal forest zone.

A further positive, although not synergistic, interaction occurs when subsistence crops 'scavenge' nutrients remaining from fertilisers applied to a cash crop rotated on the same plot (Smaling and Dixon 2006). This occurs in Dagbon as farmers crop tobacco after maize in the compound farm; the tobacco then takes up any residual nutrients from the household's waste and manure which are deposited in this area in the dry season for the maize to use.

A possible antagonistic relationship between inorganic and organic fertilisers is that the addition of SOM with a high C:N ratio can hinder chemical N uptake, at least initially. In this case microbial metabolism of C in organic matter can immobilise N used in the same reaction (Buckman and Brady 1969; de Ridder and van Keulen 1990). As in Vanlauwe *et al.'s* direct hypothesis, this N may be taken up if later remineralised (Manlay *et al.* 2002).

The evidence that non-additive effects are more likely to be synergistic than antagonistic implies that ISFM has value above its ability to maximise the quantity of available nutrients and moisture.

Such ecological considerations contribute to the debate over the relative importance of organic and inorganic components of ISFM. Advocates of ISFM in the Guinea Savanna normally focus on nutrient rather than water supply considerations, emphasising that organic amendments rarely supply sufficient nutrients for maximum yields in any one year (Friis-Hansen 1989; Vanlauwe *et al.* 2001a) especially in the case of the commonly limiting P (Quifiones *et al.* 1997). Inorganic fertilisers are therefore proposed, despite the acknowledgement that they do not improve soil structure and are too expensive for smallholders. However, authors disagree about which is the 'primary' amendment and which the 'supplement', illustrated by the use of vocabulary such as 'substitute' (Shapiro and Sanders 1998; Vanlauwe and Giller 2006) and 'complement' (Yanggen *et al.* 1998). As savanna agricultural livelihoods exist in socioeconomic relation to the rest of the world, including the capitalist economy, fertiliser is necessary. This is shown by studies like that of De Jager *et al.* (2001), who combined participatory analyses and nutrient balances to show that both a conventional and a low input system had a negative N balance and therefore required some artificial N input to sustain yields. Yet Palm *et al*. (1997) and Friis-Hansen (1989) point out that because of the unpredictable savanna agroecology and the inability of smallholders to rely on external sources of capital, fertiliser is definitely the 'supplement' to the base of organic matter. This illustrates the slight variation between Sanchez's second paradigm and ISFM, positioned at different points on the continuum from strong to weak sustainability.

Finally, smallholders' socioeconomic rationale for adopting ISFM must be re-emphasised. As each individual SFM technique requires multiple sources and types of capital, so will an integrated strategy. Many techniques rely on intravilllage or household exchanges of human, social or financial capital. Such exchanges may belong to the capitalist paradigm and entail use of an individual's financial capital. There is also scope for them to form part of the traditional economy where bartering and reciprocal exchange are more common. The poorest are excluded from the capitalist mechanisms and may lack the social capital to engage in the traditional solutions. They also lack the capital to invest in longer term strategies like agroforestry and improved fallows. They are limited to labour intensive techniques like composting, but are disadvantaged even within these if they lack human capital, indicating a potential role for participation The value of ISFM is that it ostensibly allows farmers to use the SFM technique that match their capital capabilities.

3.6 Soil summary

From the soil literature then, a picture emerges of farmers who have moved along de Ridder *et al.'*s 2004 'path of development' away from the non-equilibrial relationship between pastoralists and shifting arable cultivators towards extensive and then intensive farming. Natural nutrient capital is replaced with personal human capital and sometimes with community inputs as the traditional economy develops; it is eventually replaced by financial capital as that economy articulates with capitalism. Yet the non-equilibrial savanna climate that pastoralism and shifting cultivation were adapted to is risky to an intensified sedentary agriculture that aims to maintain a stationary, equilibrial agroecosystem. In the absence of irrigation, incorporation of organic matter delivers the critical ecosystem function of water retention that partly guards rain-fed agriculture against the unpredictable precipitation. This favours a strong sustainability viewpoint, in that the natural capital of organic matter must be maintained: although the capitals used to provide these inorganic and organic solutions may be interchangeable, as they are in a true market, the solutions themselves are not. However, as the replacement organic matter - from compost, manure and crop residues - is created by human labour it falls short of a 'very' (Turner 1992) or 'absurdly' (Daly *et al.* 1995) strong sustainability solution that would preclude agriculture altogether.

Like farmers, scientists are gradually, but surprisingly slowly, moving along a pathway towards an interdisciplinary understanding of the processes affecting soil fertility and the importance of linking agroecology and sociology (Warren *et al.* 2001; Waithaka *et al.* 2007). Ecological, agronomic, meteorological, social, political and economic data must be quantified at an appropriate scale - usually as context specific as possible. Soil is site specific. Site results cannot be extrapolated to the whole biome, but the site must be positioned within it, crucially remembering what is often neglected, the unpredictability of savanna agroecology and specifically rainfall (Mortimore 1998b; Baker 2000). The anthropogenic nature and use value of soil means its socioeconomic nestedness is also crucial. Unfortunately there is still sometimes a human-physical divide, even within the ISFM literature, which this study will aim to address by quantifying and synthesising physical, social and economic data.

The interdisciplinarity necessary for the study of rural livelihoods has been stressed throughout this and the preceding chapter. It has been seen that diverse concerns, ranging from equity to sustainability and relating to the ownership and to the availability of resources, have implications not only for choosing the appropriate strategy but also for how it can effectively be performed. The low availability of capital from all sources acts simultaneously upon different, interlinked aspects of livelihoods like soil fertility and transport. This is illustrated by the finding that in the study site, as elsewhere in SSA, farmers state that the main constraint on the uptake of organic fertilisers is a lack of transport to carry it to the field (Bationo and Mokwunye 1991b; Ganry *et al.* 2001;

Quansah *et al.* 2001; McClintock and Diop 2005; Bellwood-Howard 2009). The intersection between transport and soil is the particular mechanism through which this study explores the application of different paradigms to rural livelihoods. The following section therefore examines the sources of capital available for different modes of intravilllage transport.

3.7 Intravillage transport

If the main barrier in the study area to soil fertility, and therefore higher productivity, is transport, it is important to identify the most appropriate form and discover what types and sources of capital are required for it to be used. Although a distinction is often drawn between infrastructure and stock, both are essential. Here the focus is on the smallest scale: conveying organic materials from the homestead to the fields. Many authors have drawn attention to the prevalence of such short journeys in rural settings (Bryceson and Howe 1993), but despite the vast literature on general transport and roads in SSA there is less detailed work on intravillage and home-farm journeys than on intervillage roads (Riverson and Carapetis 1991; Sieber 1999; Lebo and Schelling 2001; Porter 2002). The links between transport and soil fertility have been observed at the very local scale by the nutrient balance studies of von Thunen's ring patterns in West African villages. Anderson and Dennis (1994) developed these, observing that the width of such rings expanded with the introduction of trucks in Tanzania. Yet policy has paid even less attention than academia to intravillage transport, although it is here that transport and soil fertility interact to affect farmers' productivity, yields and livelihoods.

Since the early 2000s attention has diverted from the issue, with the World Bank's Sub Saharan Africa Transport Programme turning its focus back to road access for rural communities in recent years (SSATP 2006; 2008). Academic analysis has similarly either stagnated, regurgitating earlier work (Porter 2007), or turned to different concerns (Porter and Abane 2008; Porter *et al.* 2009). To an extent this mirrors the way the SFM literature has drifted away from the local focus on LEISA practices back to the ISFM paradigm that promotes integration with elements of the global market. Paralleling this movement away from the small scale, government and donor assistance rarely extends to the village level - Simli, the NGO that introduced pit composting to Zaazi in partnership with MOFA, ran out of money before they were able to purchase a form of carriage for it. It is in this type of low capital situation that the practical, efficiency benefits of participation and community capital detailed in Chapter two may be most beneficial. An examination of the different transport options available in Dagbon - presented as infrastructure, walking, motor transport, and intermediate transport - will indicate which capital sources each requires and which systems of capital use may be most appropriate for them.

3.7.1 Infrastructure

For intravillage journeys, infrastructure means bush paths. Although community capital could be implicated in their improvement, such a strategy is unlikely to be feasible for the small scale bush paths used to transport compost to Dagomba farmers' fields.

In Dagbon, bush paths are sandy tracks between 50cm and 150 cm wide, often with convex sections, deep potholes and rock protrusions. In the rainy season paths may be eroded and in the dry season friction from very fluid sand makes bicycle use difficult. When loaded with sacks of compost, friction is more noticeable, the journey is slower and the bicycle is more likely to skid or fall over. These forking and diverging bush paths to farmers' fields can be several kilometers long.

Suggested solutions for the improvement of small scale transport infrastructure echo Ostrom's idea of co-production. They have mostly focused upon cost-sharing initiatives, where the 'beneficiaries' supply labour or other inputs, assisted in part by the state or other extra local funding bodies (Malmberg-Calvo 1998). Thus Riverson and Carapetis (1991) consider that the state should have some role in maintaining local infrastructure, but that private enterprise should dominate maintenance. This is echoed by Porter's (2002) consideration of the opportunities for links between state and civil society. However Anchirinah *et al*. (2000) and Porter (1997) come to the inescapable conclusion that scale determines the appropriate support system, and at the very local scale only the community or individual can carry out such maintenance, focusing on improvements along short lengths of path or at particularly difficult spots such as river crossings. This would entail an investment of the community's human, and possibly physical and financial, capital in an organised, participatory solution, with collective social capital as an access mechanism to such communal labour. It is evident that in the study site, the financial capital for this type of local operation will not be available from the state for the foreseeable future; current government endeavour is still at the stage of improving the roads linking the district towns like Kumbungu to the regional capital, Tamale. Neither has an agency external to the community either been able to provide assistance for maintaining such village footpaths. Ascribing responsibility for personal contributions of cash or labour to individual farmers would be problematic: defining 'ownership' of a bushpath used by hundreds but running along only a few farmers' fields is impossible (Porter 2002). Social capital facilitating participatory group labour therefore seems the only practicable option, and due to the low subtractablility of infrastructure (beyond the consideration of its depreciation) group labour could be seen as appropriate for this public resource, which will be used by community members in future years. Reasonable solutions for the improvement of such paths would have to be robust enough to be able to deal with the technical problems of water erosion and sand traction. Tarmac and road grading machinery are not options here, so assistance from any outside organisation would be limited to compensating the time spent by beneficiaries on the maintenance of such paths using local materials. The low technology options offered by Lebo and Schelling (2001), such as clay binding and stone pitching, are not suitable for paths several miles from a community. Sourcing and transporting such materials would be problematic. Most importantly, there is also the question of *which* 'community', and again which individuals within it, would and should participate. This echoes Francis' (2001) critique of participation in querying whether 'community' is in fact an appropriate unit of analysis and organisation. Disparate groups within the community certainly have different transport objectives - Porter (1997), Malmberg-Calvo (1994) and Bryceson and Howe (1993) point out that improving roads is of less benefit to the poor and to women, who use footpaths more than me; by diverting traffic away from off-road communities, road improvement may even have a negative influence on their lives.

It is unlikely that the seasonal repairs necessary to fix bushpaths in Dagbon could be profitable or practicable through state, participatory, capitalist or traditional systems of capital access in the near future. A more fruitful exercise may therefore be to shift the focus to the modes of transport that can appropriately be used on them.

3.7.2 Motor transport

Despite its attractiveness to Dagomba smallholders, motor transport is at present almost unfeasible in the rural environment of Dagbon partly because of the poor physical infrastructure but more crucially as a result of the necessary high financial capital investment it entails (Fonteh 2010). Farm access is limited to narrow, sandy paths, and the only forms of motorised transport that can travel to the fields are tractors, motorbikes and power tillers.

It is certainly possible to hire a tractor to convey manure to the field. If the tractor is available and the costs are comparable to those of fertiliser, the benefits in terms of SOM improvement make this a serious option, which several richer farmers in villages around the study sites have pursued. This could bear out Ellis and Hines' (1998) consideration that motorised transport can be financially 'efficient' if hired from private owners of this means of production. Although conventional motorised taxis do not run in rural areas like the study villages, a market sometimes functions for tractor transport of goods on market days and tractors are also hired to transport produce back to the village from bush farms. The vast majority of Northern Ghanaian smallholder farmers in the 21st century enter the capitalist market as they hire tractors to plough their fields, but the fact that few hire tractors to convey organic fertilisers to those fields implies that the additional cost of bringing a trailer full of manure to the farm and spreading it before ploughing is prohibitive. This confirms that the low demand and high price of much hired motorised transport in off-road settlements are mutually reinforcing (Riverson and Carapetis 1991; Ellis and Hines 1998; Porter 2002).

The high cost of motorised transport and fuel means that its use will involve integration into a capitalist economy involving cash, ownership or hiring to some degree. Yet in the study site, the state enters the story, in an illustration of the type of structural functionalism policy Nkrumah espoused and SAPs tried to remove. The Ghanaian government is promoting tractor use by making part-subsidised loans for tractors available to farmers. As part of the 2009 Northern Rural Growth Programme (NRGP), in partnership with the African Development Bank (AfDB) and the International Fund for Agricultural Development, richer farmers who raise 40-60% of the cost of a tractor - 6,000 GhC for the smallest model to 12,000 GhC for the largest (Zaney 2011) - can apply for a loan through an agricultural bank to help them with the rest, which they will eventually pay off (Modernghana.com 2010; Salifu 2010). This promotes private ownership and a hire market, part of the commercialisation, mechanisation and modernisation through markets that is a key component of the state's drive to greater productivity in the North (MOFA 2007; 2011b). Indeed, conversation with any MOFA officer will confirm that the ministry's emphasis is now on 'farming as a business'. Increasing the availability of traction would relieve pressure on one of the factors farmers cite as a major constraint to extensification and even timely cropping on existing holdings. This is another example of Ostrom's (1996) coproduction - the state supports integration into the capital market. The same strategy is echoed in the liberalised model the Government of Ghana has chosen for the fertiliser subsidy - the state leaves the distribution of fertiliser up to the producers, importers and suppliers, only intervening in the admittedly crucial sense that it foots the bill of the subsidy (Branoah Banful 2009). The NRGP is a component of this drive to industrialisation and mechanisation, the tractorisation element of which began in 2004 with import of 200 tractors (GNA 2005). The government has also secured the type of assistance it received from the AfDB from other states, as referred to in Chapter two: recent examples are the 2011 agreements in which Japan and Belarus agreed to supply tractors and other agricultural machinery to Ghana (MOFA 2011c; d). It can thus be perceived that international political relationships act as access mechanisms to the financial capital that the state needs for its policy of agricultural modernisation. As the fertiliser subsidy begins at a lower level of farmer investment than the tractor loan, it reaches more smallholders and is slowly having a small impact on their productivity. The effects of greater tractor ownership may trickle down to the smaller farmers, such as those that form the focus of this study, in the years to come, as it did in the Green Revolution areas of Asia (Baker and Jewitt 2007). With this strategy, the Ghanaian state has revitalised an element of Nkrumah's drive towards modernisation. However, the difference between the African Socialist vision of agriculture and the current government's policy is that the state no longer acts as an intermediary between the farmer and the market as parastatals and state farms did in Nkrumah's time, but rather facilitates direct contact between them in a market model (FAO/UNIDO 2008; Fonteh 2010). As was seen in the GR, such a liberalised policy as well as technologist ideology has the potential to engender higher productivity, but also accentuates differentiation between richer and poorer farmers (Lipton 1989).

Smaller private motor vehicles than tractors could also provide a compost carriage solution for their owners. Often, one or two farmers in a village own a motorbike. They can probably afford fertiliser and it is therefore not essential for them to find a vehicle to carry compost to the farm. On the other hand, the richer do generally tend to use a range of SFM techniques to maximise the flexibility of their SFM strategy and enjoy the benefits of organic as well as inorganic fertilisers. But even if richer farmers use compost as well as inorganic fertiliser, using a motorbike regularly to convey a load along a poorly maintained bush path results in wear, and this technical reason may explain why motorbikes are rarely used for transporting manure.

The power tiller is a preferred but little experienced mode of transport in the study villages, as across Northern Ghana (Anchirinah *et al.* 2000). Private ownership and hire is possible, but as for a motorbike, the obvious constraints are capital investment, availability, maintenance - including obtaining spare parts - and fuel cost.

Fuel cost is probably the least controllable capital constraint on motorised transport and continues to rise in Ghana. Subsidies were removed in 2003 (BBC 2011) and the effects of this have been compounded by rises in the global price of oil and the Ghanaian Government's repayment of the debt that the subsidy incurred to the Ghana Commercial Bank (Evans 2011). It remains to be seen whether the recent exploitation of offshore oil will make fuel more affordable to the average Ghanaian. Therefore, despite the current association of motorised transport with a state-facilitated, but largely capitalist, hiring economy, if it is to become viable for small farmers a further possible role for the state is implied in a return to fuel subsidy.

The rising cost of hiring a tractor for ploughing is usually the major cost of field crop production in 21st Century Northern Ghana (Fonteh 2010; Mensah-Bonsu 2010) and was repeatedly named as a primary financial constraint upon smallholder production by participants, confirming the difficulty farmers have in affording high fuel costs and re-emphasising that incorporation into a market can disadvantage the poorest. The actual availability of motorised traction services is a further constraint. Tractors are not owned by any of the farmers in Ypilgu or Zaazi, and seeking tractor services from owners in surrounding communities is one of farmers' major concerns in ploughing season, with late access jeopardising timely sowing and therefore yields. Tractors are thus too expensive for any individual involved in the study to use for this purpose, although their use by the wealthiest to convey compost and manure is acknowledged and has been observed in surrounding villages.

Concerns over global environmental sustainability are also relevant to this assessment of the tractor's suitability for compost carriage when the dubious effects of using fossil fuels and the local effects of erosion and compaction from machinery are considered. The personal financial capital that could be invested in motorised transport may therefore be better spent on a form of intermediate transport, hence this study's focus upon IMT and the currently commonest mode of transport - walking.

3.7.3 Walking

Especially for Dagomba women and children, walking is the main form of transport and headloading the only means of carriage (Riverson and Carapetis 1991; Porter 2002). As a greater proportion of women's journeys than men's traverse footpaths (Bryceson and Howe 1993; Malmberg-Calvo 1998) women would reap a disproportionate benefit from improved paths. Because it is the most time consuming mode of transport, walking is considered the least 'profitable' by Sieber (1999) and Riverson and Carapetis (1991). However over very short distances the time spent loading a vehicle makes headloading slightly quicker than using a vehicle to carry goods and for those experiencing the most severe capital constraints it is the only option.

3.7.4 Intermediate transport

Intermediate transport (IMT) describes vehicles such as bicycles, animals, carts, trucks and trailers that are 'halfway' between the inefficient option of walking and expensive motorised transport (Dennis 1999; Sieber 1999). Although lower cash costs mean IMT can be more readily adopted than motorised vehicles, Sieber (1999) and Bryceson and Howe (1993) consider that such outlays are still often prohibitive for women. Also, Riverson and Carapetis (1991) and Reddy (1988) emphasise that even if IMT can be more easily adopted, the costs of doing so must still be recovered, e.g. by shifting to a cash crop. The excludable, minimally subtractable nature of IMT means that as private goods they are equally likely as motor vehicles to be incorporated into a capitalist hire system (Umali-Deininger 1997; Foti *et al.* 2007), and the comparison of this with other ownership systems is the focus of Chapter five. This section will describe the five forms of IMT examined in this study: wheelbarrows, bicycles, handcarts, donkey and bullock carts, illustrated in figure 3.8, before moving on to consider the mechanisms that could mitigate the costs of their purchase.

Figure 3.8 The forms of transport examined in the study a) headloading b) Fifi bicycle c) Phoenix bicycle d) wheelbarrow e) bullock cart f) donkey cart g) trocko

3.7.4.1 Human power

Three commonly used IMT in Dagbon that rely on human as opposed to animal draft are bicycles, wheelbarrows and handtrucks or '*trockos*'.

The flat terrain of the North means cycling is common in both rural and urban areas and the Chinese-made 'Phoenix' and 'Fifi' bicycle brands are by far the commonest in Dagbon. Bicycles perform a carriage as well as a transport function – the maximum load for a 'Phoenix' is one 50kg sack of manure or two 20litre jerrycans of water. Although the vast majority of bicycles are owned and used by men, women do cycle. There are no cultural barriers against this, unlike elsewhere in Africa (Malmberg-Calvo 1994), only, it seems, a capital constraint: a bicycle cost around 100GhC in 2010. There is little literature on bicycles, as is also the case for the other two forms of transport that require mainly human capital, the handcart and wheelbarrow.

A wheelbarrow is usually most useful to those who have a specific trade need for it e.g. screeders and as such is rare in rural communities. Few functions justify the 50GhC it cost to buy in 2010.

Similarly the four-wheeled, flat bed handcart or *trocko* can be used to carry solid items like tyres and white goods and so is more often found in towns than rural villages. Its main function in communities such as the study villages has hitherto been conveying mud balls and bricks from the excavation pit to the site of house construction when the community pools its labour to build a new house. When compost is carried using the handcart it is necessary to bag it first, with the truck bearing three or four 50kg sacks of compost. There is no bicycle hire market within the community as they are widely owned, and wheelbarrows accommodate too small a lead to make them attractive to hirers. The handcart, on the other hand, with its larger capacity, can be hired for 1-2 GhC a day, justifying expenditure of the 100-200 GhC it can cost to buy.

Having considered all the *benzirra* that use human capital the analysis now turns to animal drawn modes of transport.

3.7.4.2 Animal draft

Although the Dagomba are not pastoralists, many own cattle. Cattle owners are usually men, not women, due probably not so much to cultural restrictions as capital constraints, just as with bicycles. Cattle may be kept around the homestead and cared for by young boys or entrusted to sedentary Fulani. Although cattle are not quite as culturally important to Dagombas as they are to truly pastoralist groups, Dagombas share many of the Fulani concepts about cattle. They are the most valuable animals a Dagomba can own due to their many functions. They can plough as well as carry goods in a large truck drawn by two animals, and they produce milk, manure, hide and meat. They can also be sold for cash, killed on auspicious occasions and used as bride price. Ownership of cattle in itself is prestigious and they represent a form of accumulated wealth, in addition their use value for tillage and carriage is becoming increasingly important.

A more recent arrival in Dagbon is the donkey. Most in-depth work on donkeys is from the Animal Traction Network of Eastern and Southern Africa, (ATNESA), as the West Africa Animal Traction Network was active only between 1985 and 1990, with one meeting in 2003 (ATNESA 2005). Donkey use is moving South with the tsetse-free zone (Starkey 1990), possible related to the drier past half century (Le Barbé *et al.* 2002). The tsetse barrier means the vast majority of donkeys were traditionally found in the north of Ghana, especially Upper East Region (Havard 1999) although they are now being promoted in the south (Canacoo 2004). Donkeys are more able than cattle to survive drought (Pearson *et al.* 1999) and so are used across sub-humid and arid West Africa primarily to transport goods on carts (Bobobee 1999) although their use for tillage traction is also being investigated (Anderson and Dennis 1994). Donkeys have fewer traditional uses than cattle and so are cheaper (Ngendello and Heemskerk 2004b), around 200 GhC in 2011 as opposed to 300-800 for cattle. Fernando and Starkey (2004) and Starkey (1995) consider that this may be a reason why there are fewer restrictions on womens' use of donkeys than bullocks in many places (Mpande 1994). However, although donkeys themselves are relatively cheap, carts cost more - up to 350 GhC in 2010 - with up to 50% of the cost being for imported axles and wheels (Reddy 1988). This has led Ellis and Hines (1998) to suggest reducing import taxes or subsidising them - without such subsidy, the benefits of donkey cart transportation over small distances may not repay investment. This suggestion of a possible coproductive role for the state contrasts with the neo-liberal slant of most of the IMT literature, which usually advocates hire within a capital market.

A practical constraint on the use of donkey carts in agriculture is that the approximately 2m wide cart is often wider than the narrow bush paths and consequently gets damaged. Traversing such narrow paths would be easier for a pack donkey (Sieber 1999). Pack donkeys play a key role in transferring manure to fields in the Kano close settled zone (Harris and Yusuf 2001). Hausa settlers apparently used woven leather panniers in Dagbon about 50 years ago, but after the Hausa departed they were abandoned (Authors data: 2010 interview in Voggo, Tolon-Kumbungu District). This could be explained by cultural factors - Dagombas perceive this technology as a Hausa preserve so when they left it was allowed to vanish with them. Alternatively, it could be due to the introduction of the bicycle with a rack. This can carry almost the same as a pack donkey and, although it requires more human effort, is faster. An example from Tanzania resonates with this. Pack donkeys used to carry ‘fertiliser’ to fields were replaced by bicycles, indicating that the latter were more effective (Ngendello and Heemskerk 2004a). Whether packing technology was abandoned in Dagbon on grounds of culture or efficiency, it was rejected by farmers participating in the study and so does not appear as one of the experimental treatments.

Two factors could act to offset the price of draft animals. Firstly, the manure could have value as an organic fertiliser - although the poor diet high in roughage that the donkey browses on means it will not be as nutritious as that of ruminant cattle, as confirmed in table 3.6. The colonial policies of range management informed by equilibrium ecology assumed that the value of livestock was embodied largely in its meat and reproductive capacity. However this failed to appreciate that its multiple roles, e.g. manure and traction, were equally important. Secondly, the main cost of a donkey after its purchase is supervision rather than feed, housing or veterinary care (Jones 1999). If this human capital cost were to be shared or spread, for example through group ownership, its use to carry compost to the fields could become profitable for individual group members. The cost of supervision must especially be weighed against the opportunity cost of labour migration in the dry season (Reddy 1988) and farming in the wet. Group ownership may be differentially appropriate for cattle and donkeys, considering their slightly different cultural meanings and costs. Their lower cost was the main reason that donkeys rather than cattle were used as a group object in this study and the implications of the differential cultural meaning of the two is a further theme explored in Chapter five. Table 3.7 summarizes some of the quantitative characteristics of the modes of transport reviewed.

Table 3.7 Characteristics of transport options.
Sources: (1) Dennis (1999), (2) Sieber (1999), (3) Reddy (1988), (4) Sieber (2004).

	Speed (km/h) (1,2)	Load (kg) (1,2)	Range (km/day) (1,2)	Cost ($/km) (2)	Cost compared to bicycle (3)	Cost/ benefit (4)
Walking	**4-5**	**30**	**15-20**	**1.05-1.55**	**/**	**/**
Bicycle	**12**	**40-80**	**40-50**	**/**	**1**	**4**
Wheelbarrow	**3-5**	**90-120**	**5-6**	**/**	**0.6**	**/**
Handcart	**3-5**	**180-200**	**3-12**	**0.2-0.35**	**0.4-0.7**	**/**
Cart Donkey	**3-5**	**300-500**	**20**	**0.35-0.6**	**1.5-2**	**/**
2 oxen cart	**3-5**	**900-1000**	**20**	**0.1-0.2**	**2-3**	**/**
Bicycle and trailer	10-15	125-150	30-40	0.2-0.45	1.6-1.8	/
Pack Donkey	3-5	50-80	20	0.75-1.15	0.2	4.5-11
Motorbike	30-60	50-200	100-150	/	16	
Motorbike and trailer	/	/	/	0.35-0.7	/	/
Tractor and trailer	10-15	1200	50		/	/
Power tiller	/	/	/	0.3-0.65	/	/
Truck	20-60	10,000	100+	0.1-0.5	/	/
Pickup	30–60	1,000	100+	0.3-0.65	/	/
Footpath improvements	/	/	/	/	/	8-7

Note: **Study treatments in bold.** /= no data.

The farmers involved in this study are only partly participating in the modern agricultural solution the government envisages, as they have limited integration into capitalist systems of transport hire and ownership. In the same way, their engagement with 'modern' SFM techniques is also low. As for SFM technologies, both the capitalist and traditional systems could facilitate use of compost carriage vehicles, but the market is not physically or financially accessible enough for all to hire or own tractors or become fully commercial farmers, so self-subsistence remains a pillar of smallholder agriculture in rural Dagbon. It is possible that a lower technology system, incorporating animal traction as well as organic manure, may be more achievable in the short term, especially as it demands lower capital requirements. In low capital circumstances there could also be potential for a participatory solution, considering the more subtractable nature of vehicles than SFM inputs and techniques. As ever, the systems overlap and the definitions are blurred: in a 2008 report the FAO does consider animal traction as one element of a more sustainable 'mechanisation' policy. This consideration of appropriate technology is reminiscent of the efficiency argument for participation. Chapters five and six will address the relative benefits of these diverse solutions.

3.8 Summary and implications

If political and social as well as ecological factors are important, it is necessary to consider the availability of the capitals necessary to implement the different SFM and IMT solutions and the paradigmatic significance of their use. Although ideally the preferred solution would be chosen on its merits (e.g. its sustainability and equity) and necessary capitals sourced afterwards, the reality is that the availability of capitals in any context will constrain which solution can be adopted (Powell *et al.* 1996) and how it will be implemented. This chapter has explained how the development of a SFM literature has referred to elements of each of the paradigms and capital sources examined in Chapter two and outlined the different SFM and IMT solutions available to Dagomba farmers. The results of the study will relate each of those solutions to the different ideologies and systems expounded in Chapter two.

This chapter has started to lead into the analysis; the overall picture it presents is that of a dearth, from any source, of the capital necessary to effect SFM solutions. Considering the underdevelopment of the North within Ghana - and indeed Ghana within the world economy - there is room to interpret this capital constraint as political and advocate state support. Yet providing such support through financial subsidy or inorganic fertiliser alone is inadequate. Calculating financial 'fertiliser equivalents' may help to fit nutrient balances into the needs of policy makers to allow a simplified analysis (Scoones and Toulmin 1998; Roy *et al.* 2003), but such a simplification is not helpful to those whom the policy will affect at the smallest scale as it does not address the biophysical reality of poor soil structure that smallholders have to deal with in the field. Similarly, assuming that that market integration will provide the funds to farmers to enable them to supply fertilizers is not only inequitable, it is ecologically flawed. Supplying such 'fertiliser equivalents' by any means available (Quifiones *et al.* 1997) is not enough - the importance of strong sustainability and risk reduction dictates that capital must be used in a way that is agroecologically compatible, by conserving the critical ecosystem functions of natural capital. This chapter has demonstrated that in the variable savanna climate this means the addition of SOM to retain moisture and release nutrients slowly over the growing season, hence, in the absence of sufficient organic matter for universal application, the second SFM and ISFM paradigms are most appropriate.

Lack of capital affects even such seemingly low external input technologies as the crucial organic fertilisers, most notably by constraining carriage to the field. Probably more in the case of IMT than in direct SFM, there is potential for the participatory paradigm and community capital to play a role. It is interesting to consider whether the Dagomba group labour system could extend to ownership of physical transport capital and alter the cost-benefit balance of animal transport. Community capital is typically advocated in the participation literature for reasons of empowerment. However, the inability of the state and many individuals to provide much capital in any form, especially at this local level, means that in the study area community capital may be necessary for reasons of efficiency. Indeed, this greater availability of social over financial capital is part of the reason why participatory authors favour its use. In rural Dagbon it may currently be the only practicable option. The additional non-agricultural benefits of such an arrangement illustrate that, like most aspects of livelihoods, rural transport and SFM are inextricable. Such links reinforce the usefulness of the livelihoods model as a tool for examining the effects of capital across disciplines.

There is therefore a need to find out which form of intermediate transport most effectively raises SOM, fertility and yields at this smallest scale; and, crucially for adoption, which is preferred by farmers. Following from this is a necessary identification of which capitals are required for such solutions and, most importantly, where they are found - the state, the individual, their household or their community or more likely, a mixture of all. This will have implications for the elements of different development paradigms most applicable to the study situation.

Having reviewed the literature, Chapter four can consider more thoroughly the specific methods that will be used to tackle the research questions posed in Chapter one.

Soil sampling in Ypilgu

Chapter Four

Methodology

Chapters two and three detailed the theoretical and regional background to the research questions, posing the questions of what were the best SFM and IMT strategies for Dagomba smallholders and which systems of capital use would best facilitate them. This chapter will give a more detailed description of the study site before explaining the methods used to collect the data that answered the research questions. It will examine the paradigmatic implications of each method in more detail and evaluate the success with which they were used.

4.1 Study site

The fieldwork took place in the West of the kingdom of Dagbon, in the villages of Zaazi, (9°35’16’’N, 0°51’ 38’’W) and Ypilgu (9°36’16’’N, 0°55’32’’W), each about 20km north of Tamale, the capital town of Ghana’s Northern region. The soil here is probably the upland plinthosol of the Kpelesawgu series (Adu 1995). The Lowland Rice Development Project (n.d.) which conducted a survey of soils appropriate for rice development on the slightly lower elevation of Satani, the village adjacent to Ypilgu, characterised its soils as a ‘shallow moderately well drained sandy loam containing abundant concretions and gravels underlain by ironpan’. Satani is at 400m elevation as opposed to the 450m above sea level of Ypilgu and 500m of Zaazi (Survey of Ghana 1967). The monomodal five month long rainy season is a feature of the tropical continental Guinea savanna climate (Braimoh and Vlek 2004) and rainfall data for 2007 – 2010 from the Savanna Institute for Agricultural Research (SARI) give an annual average of 1218 mm, compared to Braimoh and Vleks’ (2004) figure of 1100mm.

Figure 4.1a) Map of Ypilgu and Zaazi between Kumbungu and Savelugu. Source: Survey of Ghana (1967)

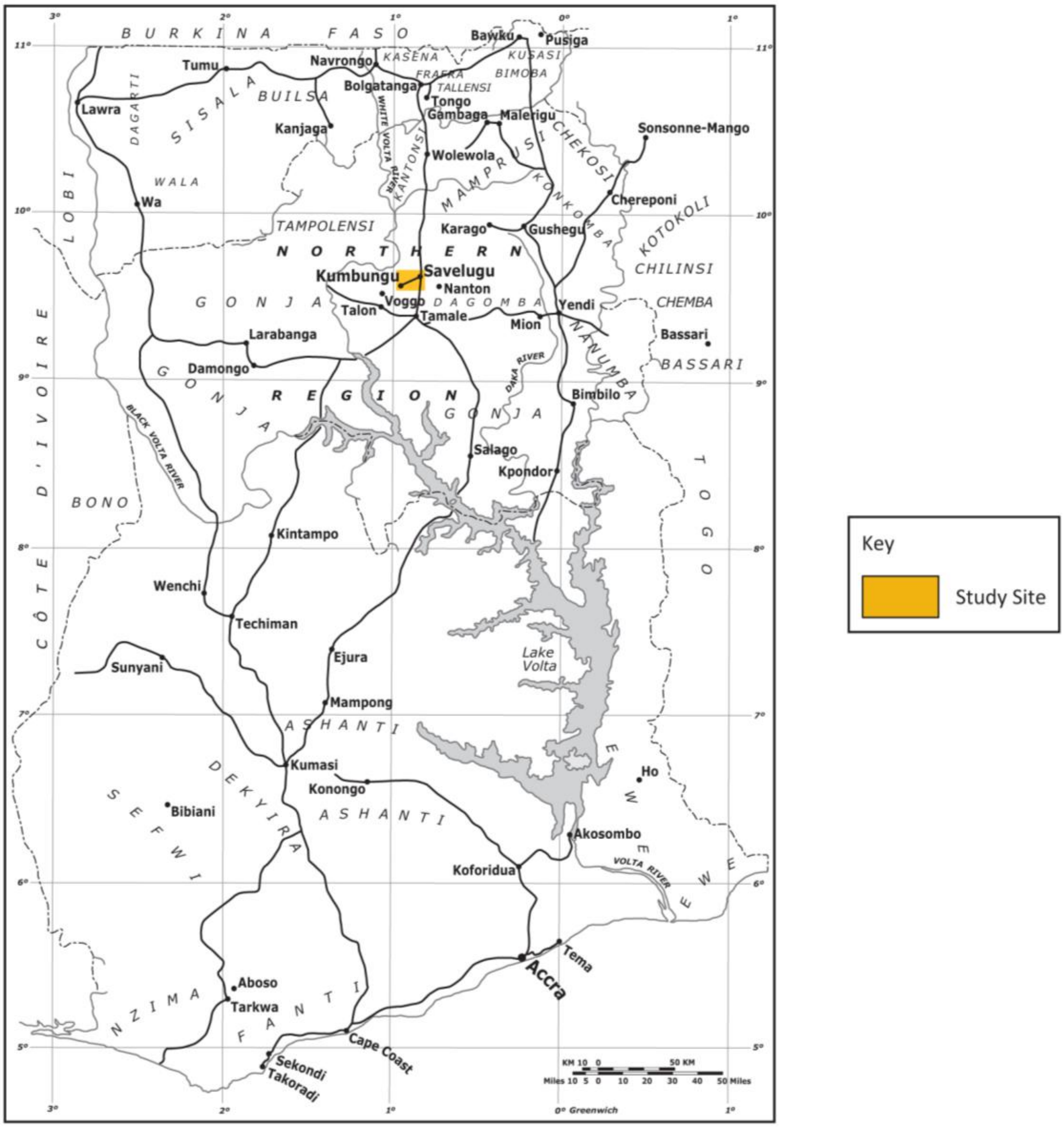

Figure 4.1b) Map of Kumbungu and Savelugu in Ghana. Source: Chernoff (1977)
Figure 4.1 Maps of the study area

4.2 Dagomba farm household system

Some of the relevant aspects of the Dagomba farm household system have been covered, but a more detailed description of the remaining cultural and agroecological features will help to appreciate how the different types of capital described in preceding chapters interact with some of the context specific concepts referred to in the results. It is more representative to refer to some of these concepts using Dagbanli rather than English, so a further purpose of this section is to introduce some of the necessary terminology.

4.2.1 Household roles

The Dagomba are a patrilineal ethnic group. Extended families generally live in polygynous households which subdivide when they become overcrowded, so households may have as few as three or as many as over 50 members. Houses often take the personal name or traditional title of the male household head or 'landlord', adding the suffix '*yilli*', meaning 'house'. Most traditional titles are suffixed '*naa*', or 'king/chief', no matter which of the many levels of the strongly hierarchical Dagomba chieftaincy structure the bearer sits within. Not all household members are related. Nieces, nephews, grandchildren, in-laws and more distant or even non relatives may become temporary or permanent members of a household and contribute their labour to the family farm. Girls who go to help a female relative, usually the paternal aunt, are termed *piringas,* and boys, *nahangas*. They play important roles in the household economy, especially the young boys as cowherds, a job usually reserved specifically for children.

4.2.2 Landownership, crops and productive roles

Landowners - almost always men - inherit land from their fathers. Chapters two and three mentioned the resultant decrease in land availability as family plots are subdivided between sons. Some areas still use the bush fallowing system recorded in the study area as late as 1973 (Oppong 1973). However, around Tamale fallows have shortened and disappeared and crop rotation and fertilisation are increasingly used. Traditionally, shifting cultivators cropped yam, millet and occasionally bambara beans, using hoes to ridge, mound and weed. Introduction of new technology as well as declining soil fertility have resulted in the shift towards cultivation of improved varieties of maize and groundnut on fields ploughed by tractors and bullocks and with the application of agrochemicals. Intercropping, especially maize-millet-legume combinations, is still common. Vegetables for soups, commonly leaf vegetables and okra, are planted by women at their husbands' field boundaries. These, along with pepper and tomatoes, may also be cash crops, especially in irrigated areas. The major cash field crops are groundnut and rice, grown mostly by junior men but also sometimes by women and landlords. Soya and other beans are also occasional cash crops. As for tubers, cassava is sometimes mounded alongside yam as a staple. It is the landlords' responsibility to provide such staples, the most important of which is currently maize. The vast majority of households eat the staple maize dish as a group. Maize cultivated in Dagbon is traditionally and still largely grown for household consumption, and when the landlord's supply is finished it is replaced by the produce of any other household members who have grown maize. If a surplus remains at the end of the year when the next crop is ready to harvest those members may sell it. As the main provider of food, the landlord and his maize farm command the household labour in the cooler mornings; those with their own farms work on them in the evenings when work on the landlord's farm is finished and the sun is going down.

4.2.3 Field cropping patterns

The location of the crops detailed in the preceding section is determined by spatial patterns of soil fertility and temporal rainfall patterns. The bands of fertility long noted around West African settlements are also observed in Dagbon. In land limited settlements such as the study villages that use compound or '*sanbanni*' (literally 'outside') farms, these more fertile spaces are dedicated to maize. The proximity to free ranging livestock precludes the sowing early planted crops here. Maize must be sown later than yam and groundnut as it requires more moisture and cannot therefore be planted before the rains seriously set in, usually around June. It also needs the more fertile land around the village and is more difficult to transport long distances. Elders must therefore stipulate the date animals in the village must be tethered so *sanbanni* maize can be sown without animal disturbance. Maize grown in the *sanbanni* farm is often the 'yellow', local variety that matures in three months, and invariably goes towards feeding the household.

The '*puun*i' (literally 'farm' or 'field') bush farms, on the other hand, can support crop rotation. Groundnuts and 'white', often high-yielding, varieties of maize that need four months to mature can be sown earlier in these bush farms with less risk of animals uprooting them. However, crop rotation is most likely to occur in fields of intermediate distance to the homestead due to the relative ease of transporting compost to and maize from these fields as compared to those in the deep bush.

4.2.4 Fertilisation and crop livestock integration

As Tamale expands and populations rise, the decrease in land availability in the peri-urban zone has led farmers to adopt and adapt the range of SFM techniques described in Chapters two and three, including inorganic fertilisers ('*kulum*'), manuring, composting ('*kulum tam'*), refuse ('*tampooli'*) application, green manure/crop residue incorporation, pollarding, double ploughing, legume rotation and ridging.

Increased crop-livestock integration (CLI) facilitates many of these techniques. Casual livestock ownership has historically played a role in Dagomba livelihood strategies. However, as Dagomba are not traditionally herders, manure contracts and herding arrangements with Fulani were more popular in former times and only over the past 30 years or so has more attention been paid to animal confinement, stall feeding rather than grazing and manure collection. Such techniques have often been introduced by NGOs: in Ypilgu, CLI and composting were simultaneously introduced by Opportunity Industrialization Centre (OIC), an NGO that donated small ruminants to 30 group members and asked them to 'pass on' five offspring to their peers. Over the same period Dagomba smallholders have adopted different modes of transport, vehicles or '*benzirra*' (singular *benzirigu*, literally 'something that carries') to help carry organic amendments to the field. The oldest form of transport is headloading using headpans or '*tahali'* but bicycles have been used for up to 40 years, and have more recently been joined by bullock carts and t*rockos,* with donkey carts and wheelbarrows the latest additions.

4.3 Research aim, questions, and project outline

The fieldwork was carried out primarily during the 2010 farming season, following a 2008-9 pilot project that identified the barriers to composting. The main finding of that pilot was that insufficient capital limited transportation of organic amendments to the field, indicating the need for further research investigating the solution to this problem (Bellwood-Howard 2009). Accordingly consent was sought from participant farmers to collect data for this study, which aims to answer the question posed in Chapter one:

How do Dagomba farmers' capital endowments act through transport provision and its interaction with soil fertility management to affect their yields?

This is broken down further:

1. How can smallholder farmers best carry compost to their maize farms and what are the capital requirements of that strategy?

2. What are the comparative benefits and capital requirements of different SFM strategies, in particular composts and inorganic fertilisers?

3. How do different capital use systems interact to facilitate effective SFM in Dagbon?

In referring to capital 'requirements', the research questions consider the five capitals indicated by the livelihoods model and the five sources identified in Chapter two: the individual, the household, the community, the state and outside organisations. Consideration of these capital sources at local level leads to contemplation of the relevance of the capitalist, statist, participatory and traditional paradigms to the study area and the systems of ownership, use and exchange linked to them.

In order to answer these research questions, two linked experiments were performed. Farmers in each of the two villages were invited to participate in the experiments. Twenty-eight farmers initially joined the group in Zaazi and thirty-one in Ypilgu. Throughout the course of the research some decided to leave the group and others joined voluntarily or were invited to do so if they were observed taking part in composting activities and were identified as useful key informants. Some farmers also decided to carry compost to more than one farm. The result was that data from carriage to 79 farms was collected. To address the issues of transport in question 1, farmers compared the use of six forms of transport under three systems of ownership to carry compost. Individuals used their own headpans and bicycles, a handtruck and bullock cart were hired with research funds for farmers to use (although farmers provided their own bullocks), and similarly a wheelbarrow and donkey and cart were purchased for ownership by the group in each village. The terms of use of the group means of transport were communally agreed as described in table 4.1.

Table 4.1 Fees for compost carriage using donkeys

Site	**1 load compost maize for group members**	**1 load compost to maize for non group members**	**1 load compost to cash crops**	**1 load mud for building**	**1 oil drum water**	**1 sack goods to market**
Zaazi	free	free	free	1 GhC per trip	50 GhP per trip	1 Ghc per trip
Ypilgu	Free in 2010, 1 GHC all day in 2011	50 GhP-1 GhC per trip depending on farm distance	50GhP per trip	1 GhC per trip	50 GhP per trip	1 Ghc per trip

Hiring a tractor would have been an interesting and relevant intervention. Doing so would have meant the study would have to deal more thoroughly with questions related to the effect of the government loan package on these communities and would necessitate a closer consideration of the contrasting effects of mechanical as opposed to draft tillage. The issues arising from those questions are worthy of their own study. Their enormous scope, while relevant to the themes with which this work is concerned, would dilute the focus somewhat. Another reason tractor hire did not constitute one of the experimental treatments was that the study, with its practical bent, aimed to examine primarily those solutions that might be feasible for farmers even without the researcher's continued intervention. The limited financial capital of farmers in the study site and the lack of tractor services in either village make this less possible, although admittedly this does not mean it could not ever become so. However, this links to the ultimate constraint - the project budget could not support this popular option, costing round 20GhC/trip, for more than a few farmers. There were no obvious grounds upon which to fairly select a few lucky individuals to test this treatment, and doing so would not have produced a sample size large enough to be of much value. This financial constraint echoes the limitations that farmers find themselves under, essentially the reason why this study focuses on IMT rather than motorised transport.

An economic analysis of the efficacy of each of the six selected modes of transport provided quantitative data related to this question. Surveys and interviews about farmers' preferences supported this and facilitated conjecture on the most amenable systems of ownership and capital use and the development paradigms upon which they draw.

Answering the second research question, relating directly to soil fertility, 59 farmers compared maize growth parameters and yields in plots applied with compost and fertiliser in their maize fields. Soil nutrient levels were measured in 22 farms in Ypilgu and eight in Zaazi. The capital requirements of different SFM techniques were assessed in interviews and again implications drawn in terms of the development paradigms they suggest.

Identifying the capitals necessary for different SFM techniques and IMT modes, and their sources, begins to answer the third question. Group discussions and participant observation yielded further data that helped to elucidate how the different systems of capital access interacted to facilitate farmers' access to appropriate SFM and IMT, and the paradigm that implies.

The research took place between January and November 2010 and March and July 2011. A timeline for that period is found in table 4.2.

Table 4.2 Project timeline

Month/year	Activity
1/10	Identify farmers and ask them to choose which forms of transport they will test
1/10	Design forms to record carriage of compost
1-2/10	Conduct interviews collecting qualitative data on perceptions of fertilisation and transport techniques and mapping fields to be used in the experiment
2/10	Purchase donkeys and carts
2/10	Begin and record efficiency of carriage of compost to fields using bullock carts, donkey carts, handcarts, bicycles, wheelbarrows, and head carriage
6/10	Begin sowing maize
6/10	Begin first round of testing soil in composted and non composted patches of maize fields
7-8/10	Apply fertiliser to selected patches
7/10	Begin second round of soil testing and measurement of growth parameters
8/10	Begin questionnaire-interviews collecting farmers' assessment of the performance of their selected transport methods and fertilisation techniques
9/10	Begin maize harvesting and recording of yield. Third round of soil testing
4/11	Third round of soil tests. Continue participant observation
6/11	Second round of questionnaire-interviews

4.4 Research ideology and methodological challenges

The project was heavily field-based and the use of field rather than lab and greenhouse data makes the results relevant and applicable to farmers' practice (Orodno 1990; Bationo *et al.* 1998). Only field data can capture the context-specific human-physical interactions such an interdisciplinary study aims to analyse, as government and research organisations often lack the human resources to pursue on-farm trials, leaving a gap that this study fills (Osmond and Riha 1996).

The project necessarily falls into the space between action and research. Although some of the more descriptive participatory methodologies were criticised in Chapter three, in working closely with farmers this project adopts aspects of the participatory ideology. The experiment was researcher designed, so in its overall aim it was not truly participatory: the farmers may have had different ideas about which themes were more centrally important to their lives. Indeed, when the project was introduced, women in Ypilgu commented that this was a male issue and other issues were more important to women than compost. The design of the experiments was more strongly influenced by members of the farmer groups than was selection of the subject matter, as they selected the *benzirra* that would be tested. Such practical elements of participatory ideology are sensible, normal procedure in fieldwork: it is impossible to perform the experiment without the input of the participants!

Participants made it clear throughout the data collection period for the pilot project that they expected benefits to accrue to them through participation in a research effort. This presents no conflict with the ultimate objective of the research, having as one of its aims the identification of an appropriate form of transport to convey organic amendments to the fields. However the participatory nature of the research effort did complicate somewhat the process of collecting data, as farmers' practice forced data collection procedures to be modified. As noted by Millar (1994), farmers themselves experiment, and as such were not entirely novices to the research procedure. Their own experiments, however, are rarely controlled (Martin and Sherington 1997); if a practice is found to work it is adopted. Such instances were related by participant farmers. For example, Dohina Abdul-Rahaman Abdulai in Zaazi, explained how one year he planted half a field with the higher yielding 'white' variety of maize and applied no amendments and another half of the field with a traditionally lower yielding 'yellow' variety , applying compost to this half. He interpreted the results of this experiment as indicating that compost could help the yellow variety to yield as much as the white, but as there was no control the experiment does not stand up to scientific scrutiny. Similar dilemmas were brought to light throughout the data collection period, for example whilst carrying compost to the fields. Two situations in particular presented potential disjunctures between the needs of 'the researcher's science' and 'the farmers' practice'.

Firstly, attempting to observe farmers' practice - in this instance how they applied and spread compost around the field - precludes controlled experiment. A wide variety of techniques and rates of compost application were observed before it was decided to hold a demonstration meeting aiming to standardise application rates as far as possible. In one sense such a wide variety of practices makes less quantitative data available to the researcher, who can no longer correlate area covered by compost against time spent carrying it and must be content with simply analysing volume carried. Yet in another sense it reveals a richer bank of qualitative data on the variable practices which may be more appropriate for different locations, varieties or land preparation methods. Participatory authors would note that sharing such information in a meeting contributes to a subsidiary benefit of the research: farmer-to-farmer teaching and learning.

Secondly, farmers may partially reject the terms of a controlled experiment. Although many farmers initially agreed to test the bullock cart, handcart and wheelbarrow, towards the end of the carriage period they forsook these modes of carriage for the donkey. Again, on the one hand this undermines the quality of the data, in that it leaves the researcher with few observations in these groups when performing statistical analyses. On the other hand, such farmers' decisions are data in themselves - these farmers have observed their colleagues' practice and drawn their own conclusions before the whole round of data collection and statistical analysis has been completed. They explained the qualitative reasons for their decisions; in this case although the bullock cart carried more compost/hour the onset of groundnut farming before maize sowing meant bullocks and child labour were unavailable in May.

These considerations bring to light another of the main methodological themes of the research - the relative merits of qualitative and quantitative data. The current study adhered to the orthodoxy prevailing in the social sciences (and indeed increasingly in other disciplines) that a combination of 'hard' and 'soft' data, e.g. soil tests and interviews, is the most fruitful. In the SFM context this has been noted by, for example, Ishida *et al.* (2001). This study followed such an interdisciplinary strategy, the benefits of which will be illustrated as the various methods of data collection used are detailed, roughly in the chronological order in which they were performed in the field.

4.5 Interviews

All 59 initial participant farmers were interviewed in early 2010 in the field in which they intended to apply compost. A topic guide is found in Appendix 2. The aims of these interviews were:

1. To act as an initial exploratory tool, gathering themes of importance to farmers in order to design tests or questions to explore them further.
2. To record the history of each field. These data were used to make a sketch map of each farm. The maps served to explain yield and growth parameter data that

could not be explained by application of compost and fertiliser and to guide selection of sites for soil sampling.

3. To elucidate farmers' qualitative perceptions and experiences of both fertilisation and transportation practice which might explain their actions or other results obtained.

4.6 Group meetings

Although not initially conceived as a method of formal data collection but rather a means of disseminating information, these fora often threw up some of the most valuable qualitative data. Meetings were held to discuss issues such as the order of use of forms of transport and the optimum rate of compost spreading. In these meetings, the rationale behind farmers' decisions was revealed and data were collected that, as participatory authors note, would have taken several times as long to collect by interview (Mayoux and Chambers 2005).

However, it should be remembered that interview and group meetings are not perfect substitutes – individuals' experiences differ from consensus and majority opinions. Indeed, authors critiquing participatory methods point out that differences of opinion may be overridden in a group setting (Cooke 2001). This was indeed observed to varying degrees. Upon matters of opinion e.g. whether fertiliser or compost was better there was disagreement amongst farmers, yet when it came to decision making, e.g. whether to change modes of transport when the donkey was sick or what to do when it died, groups often seemed to effortlessly arrive at unanimity, a process sometimes associated with African decision-making more than democracy (Kingsolver 1998). The final word stemmed sometimes from the intervention of chiefs and elders and sometimes from collective decision making.

Differences between group and individual decisions had implications for the type of data collected; one farmer who initially used the handcart agreed in a conversation to continue to do so for the sake of data collection despite his preference for the donkey. Yet in a meeting to finalise the matter, the farmers using the handcart stated as a group that they would all switch to the donkey. This did reduce the number of observations of use of the *trocko*, weakening the power of statistical tests performed upon that data set. Yet In this group forum farmers presented the qualitative data that the labour requirements of the *trocko* conflicted with groundnut sowing in late May, something the individual farmer had not expressed, maybe because of the language barrier in a one-to-one conversation.

Three methodological points are illustrated here - the difference between group and individual decisions, probably because of differential power relations between farmers and researcher in such fora, the incompatibilities between controlled experiments and qualitative data and the importance of language and interpretation.

4.6.1Interpretation and language

Both interviews and group meetings required interpretation, performed mostly by the initial gatekeeper in Ypilgu and an interpreter introduced to the community for the purposes of the project in Zaazi. In instances when these people were unavailable for meetings substitutes were found from within the communities, e.g. schoolteachers.

It is undeniable that the language barrier is one of the major limitations of this research. It constrained optimum communication between the researcher and farmers. The process of adjusting and adapting to varying methodologies could have been better handled with better communication. Despite regular meetings with the whole group and individuals and some diligent interpretation, the research methodology could have been more efficiently streamlined and adjusted by a researcher with linguistic skills beyond a basic working knowledge of agricultural Dagbanli. This would have been particularly useful in situations like the recording of carriage times and communication with the family members of participant farmers, who carried out many of the tasks recorded during the course of the project such as compost carriage and fertiliser application. The only method researchers can use to curtail this constraint is to learn the language thoroughly and triangulate data as much as possible using methods like participant observation and photography.

The use of untrained interpreters also presents interesting methodological dilemmas. The interpreters undoubtedly did not translate Dagbanli to English as directly as a professional would have done. Yet it is impossible to decide whether a professional interpreter would have uncovered more valuable data than this team of an untrained interpreter and a researcher with a rudimentary Dagbanli vocabulary that was nevertheless particularly rich in agricultural and local terminology. Such specific local knowledge enabled the team to understand quickly when farmers were referring to specific soil types or farming practices with which a professional interpreter from outside the area might not have been familiar. Again a cautionary note should be sounded - the researcher must be constantly alert that familiarity with their setting does not engender assumption. It is still necessary to probe respondents diligently for the underlying causalities of phenomena uncovered in the data.

Using untrained interpreters requires an additional body of knowledge on the part of the researcher: it could be argued that translation had two stages - from Dagbanli to 'Ghanaian English' and then from 'Ghanaian English' to standard English, creating an additional 'layer of meaning' (Cloke *et al.* 2004). Here the researcher's familiarity with 'Ghanaian English' is as important as the interpreters 'accurate' translation from Dagbanli to English. A particularly relevant example for this study, which is so heavily concerned with transport, is the meaning of the word 'send', which across Ghana is used by the majority of people where an English person would use the word 'take'. Only a prolonged stay in the study site can equip the researcher with the ability to discern whether the 'sender' accompanied the 'sent' object to its destination.

There were instances when the interpreters did not accurately or fully interpret the farmers' responses. This became evident as the researcher became more proficient in Dagbanli and when interpreters listened to and commented on recordings of each other's interviews.

Appointing field assistants of any type risks involvement in power politics. The villagers in Zaazi chose to replace the external interpreter with one from within their community because they were jealous that the fee paid to the interpreter was going outside the community. This may have reduced the quality and continuity of the data slightly but improved the cooperation and availability of the respondents. This appointment in itself had obvious political dimensions as the facilitator's decision to appoint his junior relative as the replacement interpreter consolidated their families' control over the project and its budget.

4.7 Economic analysis of compost carriage

Farmers tested how well each mode of transport carried compost to the farm. In Ypilgu farmers felt that they should all be required to compare one ‘improved’ form (bullock, donkey, handcart or wheelbarrow) with one ‘traditional’ one (headpan or bicycle). In Zaazi most farmers were willing to use only one of the six available forms of transport and some farmers initially stated they would be willing to use only a ‘traditional’ form. However in practice this attempt at a semi-controlled experiment unravelled. After the initial round of carrying in Ypilgu and before it had ended in Zaazi the popularity of the donkey cart became evident as more farmers forsook other forms of transport in its favour. This highlights yet again the trade-off between qualitative and quantitative data: fewer observations of the less popular forms of transport were available for statistical analysis, but the fact that they were less popular was itself an indication of the farmers’ dissatisfaction with them, a point which could then rapidly be triangulated and explained with qualitative interview and group discussion data. Somewhat alleviating the problem of fewer quantitative observations, unexpected opportunities for data collection presented themselves as farmers outside the group allowed records to be made of their activities using their own headpans and bicycles, and handcarts and bullock carts they had hired using their own capital. Thus, the qualitative data illustrated the farmers’ preference for the donkey cart whilst opportunistic data collection facilitated statistical analysis.

Quantitative carriage data were recorded on versions of the sheet presented in Appendix 3. Farmers recorded the vehicle they used, the time they began and finished carrying, the number of trips they made, and the number of people engaged in the activity. The distance from the source of the compost or manure to the farm and the approximate volume of manure carried per trip by each form of transport was also measured as described below.

The collection of quantitative data is not as straightforward as the form may appear – the farmers may take a break between trips, the number of helpers fluctuates over the period of carriage and some helpers may help more than others. As ever, these limitations may be reinterpreted as qualitative data. The major problem was the accurate recording of the start and finish time of the work by farmers who could not tell the time or were not confident using pencils. In the few instances where time was entirely unrecorded, e.g. in instances of opportunistic data collection from farmers who were not members of the group, time was estimated by the researcher performing the journey from the source of the compost to the farm.

The measurement of the distance of the farm to the source of the organic manure threw up some interesting dilemmas. A GPS receiver measures distances in straight lines and therefore does not represent the true distance travelled along a winding bushpath. The only other method available in the field was to pace out the journey and convert the number of paces to kilometres based on an average of 64 of the same person's steps/100m long measuring tape. The latter is not scientific or reproducible. Nevertheless an average of the two methods was taken. Having to make such a compromise illustrates why researchers often have to adopt the more qualitative participatory techniques criticised in Chapter three.

The approximate volume of compost carried by each mode of transport was calculated by measuring the donkey and bullock carts, wheelbarrows, headpan and sack used and calculating their volumes. This measurement was triangulated with one derived by filling each container with a known volume of sand from a two-litre tin.

A range of densities was also recorded for the different organic amendments classed as 'compost'. Sacks containing known volumes of compost measured from *tahali* were suspended from two different hanging scales. The variable densities thus recorded illustrated the difficulties of making application recommendations based on weight as opposed to volume per hectare and thereby justified the recording of volume rather than weight of compost carried.

It was initially envisaged that each farm used would supply one data set of total person-hours used to transport a certain volume of compost. However, many farmers used more than one carrying session to transport compost to their farms, fortuitously facilitating more data points than initially envisaged. It was also necessary to recognise that as people and animals become tired the relationship between amount of time expended upon carriage and volume of compost transported is not linear, meaning that using data for each carrying session rather than a total per farm actually gives a more accurate picture of the capabilities of each form of transport. The statistical analyses were therefore carried out on data collected for each carrying session as well as for farms as a whole.

The data thus collected were computed into three variables:

1. Volume of compost carried per person-hour.
2. Volume of compost carried per person-hour*kilometre. This variable corrected for the variable distances to different farms by multiplying volume of compost carried per person-hour by the distance of the path along which it was carried.
3. Volume of compost carried per 'ideal' person-hour*kilometre. Many farmers used more than the minimum number of people necessary to operate each *benzirigu* due to varying household labour availabilities. It was also sometimes difficult to determine who was actually helping and who spectating. To correct for this and facilitate comparison, volume carried per person-hour*kilometre was recalculated using the minimum number of people necessary for each mode of transport. Headloading, bicycles and wheelbarrows used one person, the donkey carts two people and the bullock cart four.

Appendix 4 gives formulae for the calculation of each of these parameters.

Chapter five will show that results using the variable 'volume per person-hour*kilometre' were most realistically explained, and the distributions of those data and those using the variable data 'volume per 'ideal' person-hour*kilometre' did not vary much, so calculations were performed using the less manipulated and transformed variable of 'volume per person-hour*kilometre'.

Data were collected on the area farmers covered with the compost they carried using a tape measure to record the area and 12 quadrat readings per area to record coverage. However as farmers all used compost of different qualities their spreading practice varied, with some spreading rich compost widely and some using poor quality compost or refuse and spreading it thickly. An intention to plough with bullocks rather than tractor also lead to more homogenous spreading as the tractor was able to scatter more discrete piles of compost across the field with its deeper plough. Data on coverage per person-hour was therefore not comparable between farms and assessment of the effectiveness of different *benzirra* was based on the more meaningful variable of volume carried per person-hour.

The coverage data were subsequently used merely to illustrate farmers' varying practice and compare it to the recommended compost application rates of 4-10 tonnes ha^{-1}. Even this was an approximation because composts and manures have different densities: a factor that also makes tonnes ha^{-1} a problematic unit for famers to transfer to practical application.

Considering this variable range of application rates and carriage methods, the question arose of how much to attempt to direct and regulate farmers practice. As noted above, variable practice prevented some planned statistical analyses but provided qualitative data on the variety of farmers' practices, and in this case also facilitated correlation between yield and the new variable of compost application rate. From a practical perspective, considering the language barrier and the fact that the experiment was taking place on farmers' working fields, it would be impossible to dictate farmers' practice even if it were desirable to do so.

Data on volume of compost carried per person-hour and per person-hour*kilometre were not normally distributed so non-parametric Kruskall-Wallis tests were used to compare mean volumes carried between different modes of transport.

4.8 Census

In order to ascertain whether the amount of compost a farmer carried was related to their personal capital endowment a census was performed in each village. An effort was made to collect data on every single person in the village to determine factors such as the availability of labour and manure to different members of each household. The questionnaire used is displayed in Appendix 5. As far as possible, it was filled in by group discussion with members of each household so individuals could triangulate each other's responses.

To facilitate statistical tests requiring categorical data, indices were compiled from the census data as described below.

4.8.1 Access to labour

Each individual was asked whether they could help in farm work and ascribed a labour score as in table 4.3. Farm tasks are usually performed on an age and gender specific basis and the main aim of this parameter was to assess how many people were available to transport compost to the field. Therefore it allocates scores based on how likely they are to be able to assist with this task.

Table 4.3 Individual scores for labour index

0	Unable to perform farm work because too old, young or disabled
0.5	A school child or a woman - unlikely to help in the day, push a truck or drive a donkey
1	A child who doesn't attend school - they can push a truck and drive a donkey
1.5	A man or teenager who can perform all carriage tasks

The scores of all individuals in the house were combined to quantify the labour the landlord had access to. Other farmers were asked who helped them on the farm and the labour scores of those people were combined to produce the score of the labour that farmer had access to. A histogram was used to gain a visual impression of the distribution of labour scores and based on farmers were divided into three categories, each containing an appropriate number of cases to facilitate valid comparison of distributions. These categories were 0-8, 8-15, and 15+ people per household.

4.8.2. Access to bicycles

Each participant farmer was allocated a score as in table 4.4

Table 4.4 Index of bicycle access

0	No bicycles in the house
0.5	They themselves don't have a bike but at least 1 person who helps them does
1	They have their own bike
1.5	They and 3 other people who help them have bikes

4.8.3 Access to *benzirra*

Each participant farmer was scored as in table 4.5. As mentioned in Chapter three, motorbikes are not used to carry compost so were not included as *benzirra.* This illustrates the iterative nature of the research process, as qualitative interview data informed the construction of the quantitative tool.

Table 4.5 Index of access to benzirra

0	No *benzirra* except *tahali* in the house
1	Any *benzirigu* except a motorbike in the house

4.8.4 Access to bullocks

Farmer scores were allocated as in table 4.6

Table 4.6 Index of access to bullocks

0	No bullocks in the house
1	Bullocks in the house

Having bullocks in the house does not necessarily guarantee that the respondent can access them. However a survey conducted in 2011 confirmed that in the study villages for 71% of respondents it did, justifying this index.

4.8.5 Livestock ownership

Table 4.7 displays the scores allocated for livestock ownership. The categories were constructed having examined histograms of animal ownership. There were thus a reasonable number of farmers in each category whilst those categories still made meaningful distinctions between disparate levels of wealth, being based on ownership of different species as well as numbers.

Table 4.7 Index of livestock ownership

0	Less than 10 fowl
1	10 fowl or 1 small ruminant
2	7 small ruminants or 1 cattle

4.8.6 Other income

The scores displayed in table 4.8 again represent a meaningful distinction between the different livelihood strategies employed in the study communities, whilst still allowing a reasonable number of people to fall into each group. Had group 1 been divided into more distinct categories there would have been too few people in each to facilitate meaningful statistical comparison of distribution.

Table 4.8 Index of income other than farming

0	Just farming
2	Vegetable farming
1	Anything else except vegetable farming e.g. petty trading or bicycle fitting

As well as facilitating correlation between capital endowment and SFM practice, the census provided data characterising each community, e.g. population size, and also served as a means of contact between researcher and participants, smoothing the path towards the later collection of interview, survey and participant observation data.

4.9 Participant observation of practice

Participating in the carriage of the compost to the field rather than leaving the farmers to record their own practices facilitated the collection of much more accurate data. For example, it became possible to record exactly how many children actually pushed the cart and how many merely ran alongside, to measure the exact volume of the sacks used, and to decide to accord a labour value of 0.5 to a farmer who spent half the carrying session carrying compost on the bicycle and the other half loading the donkey cart. The latter observation once again illustrates the value of qualitative data in giving rise to new ideas: in this case it showed synergy between modes of transport. Such qualitative data can only be collected through participant observation.

4.10 Soil characterisation

The ultimate objective of comparing the effects of organic and inorganic fertilisers on the crops was to determine whether it was worth spending capital on application of organic amendments as opposed to the commonly applied alternative, inorganic fertilisers.

A range of qualitative soil characterisation techniques adapted from the US Department of Agriculture Test Kit Guide (2001), shown in Appendix 6, were used to make an initial assessment of soil quality on two farms. Those soil test results were compared to results for adjacent permanently fallowed patches. On one, farming was taboo and on the other it was impossible due to rocks near to the surface. Wet and dry soil colour was compared to a Munsell chart. Field assessment of structure and texture was made. A slake test immersed aggregates into water and compared their reaction. Finally, root density and morphological characteristics were recorded alongside a topsoil profile characterisation.

4.11 Experimental design for composted and fertilised area

In order to compare the relative effects of compost and fertiliser on maize plants, 59 farmers agreed to provide experimental plots in their farms. Most farmers included a control area where no fertiliser of any type was applied, an area fertilised with compost alone and an area with fertiliser alone. The edges of these plots were marked with tagged sticks. Interview data were used to select sites which were as homogenous as possible in terms of cropping and fertilisation history and soil type. As far as possible, sites at the edge of fields were avoided. It was difficult to reconcile the farmers' needs with these requirements. Most farmers wanted to situate the control site beneath a tree or on a plot that had received compost or been used to grow vegetables the previous year and therefore hopefully had residual higher soil fertility. In many cases this could not be avoided. Not all farmers felt able to leave a control plot as they felt this would affect their yields to an unacceptable extent. Some farmers ridged a bund around the edge of the control plot to prevent any transport of fertiliser dissolved in rainwater into the control area. However later in the season it became apparent that even in unbunded control plots the performance of unfertilised plants was much poorer than that of fertilised plants immediately outside the plot, so little fertiliser transport was in fact taking place. Control sites at the foot of hills were also avoided as far as possible for the same reason, but if the farmers had applied compost at the foot of the hill the control site also had to be sited here to minimise differences between the soils due to the catena. Instances where data had to be removed from some sets occurred when farmers applied compost to their whole farms without leaving a control and when other conditions varied between composted and control or fertilised plots, for example different varieties or number of seeds per hill. Three farmers did not supervise the application of inorganic fertiliser to their fields by family members, so no area of their farm was left as an unfertilised control or a sole compost treatment. This reduced the available number of data points for these categories but added data on plots applied with both compost and fertiliser.

Combined application of compost and fertiliser is the recommended practice and is common and effective. It is worthy of detailed attention, especially considering its role as the central tenet of ISFM. However that treatment is not the main focus of this study. Here the comparison is between use of compost alone and fertiliser alone in order to elucidate where scarce capital and resources should be targeted *within* the recommended ISFM strategy. Had there been more time and resources, an application of combined compost and fertiliser would have been an instructive third treatment to examine, and this should be the focus of future research.

Compound fertiliser was generally applied three to four weeks after planting and ammonia was applied at the tasseling stage. A crucial aspect of this study is that the type, rate and timing of inorganic fertiliser application were at the discretion of the farmer. Farmers made their own compost and purchased their own fertiliser. As described in Chapters two and three, in 2010 the government subsidised fertiliser, which was bought for 18GhC per 50kg bag of ammonia and 27 GhC per bag of compound. The treatment each individual applied thus reflected their capabilities. This is the most important aspect of the experimental design as the aim of the research is to see how compost and fertiliser perform in the smallholders' capital environment. It accentuates the difference between on-station and on-farm trials: when treatments are tried on the agricultural station their *potential* performance is assessed. On the farm their compatibility with field conditions is realised. Many field trials stipulate rates and times of application and inputs are supplied by researchers. This trial goes a step further: as fertiliser inputs were supplied by farmers it tests whether they are able to provide the required amount of them on an annual basis in their real life, capital-limited situation. This is one of the main reasons for the disjuncture between the implications of the results in Chapter six and those stemming from the current ISFM orthodoxy. As the results of this study were defined by smallholders' real conditions it could be argued that the implications drawn from them are more relevant. A drawback of the farmer-determined treatments is that they are highly variable and poorly quantified. Farmers' self reporting is not as reliable as researchers' application of treatments, and this may explain the wide range of reported application rates. On the other hand, the results may be accurate but represent a wide range of practices, meaning statistical comparison is less meaningful.

4.11.1 Growth parameters

Eight growth parameters of maize plants were compared between control, composted and inorganically fertilised areas.

Twelve plants were selected within the control, composted and fertilised plots using a random number table. Height, stem thickness, leaf length, cobs per plant, cob length and width of each were measured. It was necessary to measure height and leaf length before tasseling period as many farmers removed the top half of the plant to feed to animals once the cobs had begun to form. Cob length and width and cobs per plant could not, however, be measured until the cobs had fully formed. To measure the seventh and eighth growth parameters - time to 50% tasseling and percentage of plants that did not yield - a square within the treatment plot was demarcated with string when the first tassel appeared in a farm. The exact number of plants in each square - approximately 100 - was recorded. The square was visited daily and the date noted when tassels were visible on 50% of the plants. The same square was used at harvesting time to note how many of the plants in the square had not yielded cobs or had yielded cobs without dents.

The use of this square complicated farmers' fertiliser application. Despite directing the positioning of the fertiliser, compost and control areas, some farmers did not observe the demarcation of the 50% tasseling plot. All the farmers were informed of the purpose of the string plot, yet possibly as string is more visible than the tagged sticks used to mark the edge of the treatment plots some thought the string marked a new control plot and applied fertiliser everywhere except inside these plots. This also occurred when the farmer had not relayed the information to his family and they applied fertiliser in his absence. With 60 farms in two villages and many farmers applying fertiliser concurrently it was not possible for the researcher to observe each fertiliser application. However this problem did not lead to the loss of any data. When fertiliser was applied to the boundary of the string square in the control or compost plot this plot could still be used to collect soil samples and measure growth parameters. It was merely unfortunate that the total available population of plants under that treatment was then reduced to approximately 100 so the sample of 12 plants then represented about 12% of the population. When farmers applied fertiliser outside the 50% tasseling square in the fertiliser area, provided 50% of the plants had not already tasselled, the square could be moved to an adjacent area that had received fertiliser. It did make it more difficult to relocate the control and compost plots the following year to perform the fourth round of soil tests, but GPS data on the location of the squares solved that problem.

This challenge can be attributed to a combination of the communication and language barrier and a sample size so big that one researcher could not oversee it all.

4.11.2 Yield

Yields are usually measured in tonnes of dried maize ha^{-1}. This was not possible here as the equipment to dry maize to standard moisture content was unavailable. Farmers sell maize by the bowl in Dagbon so the study also measured yield by volume using a 400ml cup measure as the unit. Yield per 50 cobs rather than per unit area was measured for two reasons. Firstly, non-uniform planting distances between farms and to a lesser extent between areas within farms meant measurements per unit area would not be comparable. Secondly, it was much easier for farmers to collect 50 cobs than to measure a fixed area in their farms to collect cobs from (Gouse *et al.* 2005). Had they been asked to do the latter it is unlikely the data would have been collected.

However there are two problems with the ‘yield per 50 plants’ parameter. Measuring volume of maize gained from 50 cobs rather than 50 plants means the plants that did not yield or that yielded two cobs are not taken into consideration and therefore it is not a true reflection of return of the amount of seed invested in the farm. This is why the percentage of plants that did not yield was also measured. Also, time constraints meant farmers tended to collect the 50 cobs from one area of the farm, sometimes the 50% tasseling plot demarcated with string, rather than taking a random sample from the whole farm. As with fertiliser application, when many farmers were harvesting concurrently it was not possible for the researcher to be present at harvesting in all the fields in order to direct random sampling. These points illustrate the dangers of relying on one parameter alone and hence the importance of the type of triangulation that was performed here.

Interfarm comparison of yield and growth parameters was less meaningful because of different growing conditions in different farms. These include soil type, farm history, plough type, sowing date, variety of maize, planting distance, plants per hill, weeding regime and application of herbicide as well as the variable practice within the parameters the study actually examined, such as quality and rate of compost application and fertiliser timing, combination and rate of application. Maize drying times and therefore moisture content and volume per dent also varied between farmers. This inability to make interfarm comparisons is one of the consequences of deciding to do a semi-controlled farm-based rather than a controlled lab or station-based field trial: the study focuses upon farmers' capital capabilities and therefore cannot not control for growing conditions. As a result the intrafarm comparisons made between composted, control and fertiliser plots are more meaningful than those made between farms.

The difference in cultural conditions between farms necessitated another decision: whether to display raw yield data or to correct for intrafarm differences by displaying fertiliser yield data as a percentage of control or compost treatments. However the ability to perform this correction conflicted with another quirk in the data. It has already been mentioned that some farms lacked controls or had applied fertiliser to plots originally intended to be for compost only. This meant that such farms' data would have to be excluded when using a parameter that expressed fertiliser yield as a percentage of control or compost yield. In the end all three parameters were calculated and the same graphical and statistical analysis performed for all three sets. The different permutations of the data made very little difference to the results so the less manipulated raw data, using the parameter of cups of maize yield per 50 plants, was used. More data points could then be included in statistical tests, improving their robustness.

4.12 Soil chemical tests

Soil macronutrients levels were compared between the control area of each farm and the areas applied with compost and fertiliser. Two plots that were permanently fallow, because farming was taboo on those sites, were also sampled.

4.12.1 Sampling

Soil was sampled from 30 farms. The farms were chosen on the basis of their cropping and fertilisation history using data from the first interviews. As far as possible, farms with similar histories were sampled. In order to choose farms representative of those that had the most severe soil fertility constraint, farms that had been sown with maize the previous year were chosen. As described earlier in this chapter, farms that are likely to be sown with maize each year are also within the distance band most likely to have compost applied. As heterogeneous, patchy compost application within each field is the norm it was not possible to identify precisely where in a field compost had been applied the previous year, so an attempt was made to use fields that had not previously had compost applied in order to minimise residual organic matter in the soil that would confound the treatment applied in 2010.

The sampling timetable is displayed in table 4.9

Table 4.9 Soil sampling timetable

	Control plots	Compost plots	Inorganic fertiliser plots	Fallow
Before sowing in 2010	x	x	One sample	x
At tasseling	x	x	x	X
At harvesting	x	x	x	X
Before sowing in 2011	x	x	x	x

Note: x = sample taken

Fertiliser was not applied pre-emergence, so the sample taken before sowing in 2010 merely confirms that compost supplied nutrients to the soil and gives an idea of the background nutrient level in the study area. The sample taken at the tasseling stage is more important as it shows the level of nutrients available to the forming cobs. This sample was taken either after the application of ammonia or when the plants had reached 50% tasseling and the farmer said he would not apply ammonia. There was one instance where the sample was taken very late as the farmer insisted he would apply ammonia but did not. However, as the focus is on intra rather than intersite differences this posed no problem. Harvest-time samples were taken when all maize had dried on the plant rather than waiting until the physical act of harvesting, because some farmers did not remove the cobs from the plants until long after they had dried due to the labour requirements of other farm tasks.

Although composted plants often tasselled long before those to which fertiliser had been applied, or those in the control plot, the samples were taken from all three areas on the same day or consecutive days to improve comparability between the sites. If samples were taken on different dates other factors such as weather or pollution events, biological soil reactions or animal disturbance could intervene to confound the results and make comparison between different areas in the same farm impossible.

Twelve 15cm cores were taken in each treatment plot with an iron tube of 15mm diameter. The twelve cores were homogenised in a plastic bucket, and the resulting sample immediately labelled and transferred into a plastic bag, stored on a rack in dark dry conditions and transferred to the lab within one week of sampling.

The zig-zag sampling method was used. Traditional sampling advice for temperate regions is one sample per acre comprising 5-25 cores (Carter and Gregorich 2006). However, tropical soils can be far more heterogenous, even within fields, not only as a result of past management practice but also due to the strong catena variations in West African savanna soils. This was borne out by literature on the Dagbanli catena (Runge-Metzger and Diehl 1993 ; Adu 1995) and in farmers' interviews, with five broad types of soil being identified and interfield variation the norm. Therefore the areas represented by soil samples in this study were smaller than an acre and much care was taken when deciding where to sample from, avoiding patches where the influence of other factors such as elevation or termite mounds were likely to mask those of soil fertility amendment. Before fertiliser application, samples from the composted area and an adjacent control of a similar area from a similar soil type were taken. If the farmers moved the site of the control area later, as described in section 4.11.1, samples were taken from the new control. When fertiliser was used, most farmers applied it to the majority of the field, so in order to reduce the effects of inherent soil type heterogeneity between samples the zigzag sampling for the fertilised portion was carried out in a similar way to the first control - in a portion of the farm adjacent to the composted area and of a similar size. After harvesting the final sample was taken in the same areas as the tasseling sample.

Section 4.11 described how some farmers applied fertiliser to the entire farm save the area demarcated with string for measurement of the 50% tasseling parameter. If this was the case, samples taken from within or outside that boundary were taken at least 60 cm from the string to avoid contamination with another treatment.

4.12.2 Analysis

Chemical analyses were carried out at the soil laboratory of the Savanna Agricultural Research Institute (SARI). Once in the laboratory samples were air dried and ground with a ceramic pestle and mortar and carbon, nitrogen, phosphorous and potassium levels were tested according to the methods detailed in Appendix 7.

Mean measurements from all 30 farms were calculated and graphed across the sampling period.

4.13 Water retention test

In interviews, several farmers stated that soil containing compost retained water better than soil without. Accordingly, in another illustration of the iterative research methodology, an assay was designed to test whether soils containing organic matter and compost had significantly different bulk density or retained more water after rain than those not amended with compost. As this test examines physical properties of soil it was necessary for it to take place *in situ*: as the samples were not disturbed by removing them from the ground their structure remained intact (Lal 1979; Dudal and Deckers 1993).

Thirty sites with a high level of organic matter and 30 assumed to be without organic inputs were chosen. The test measured water content of all sites the day after rain and then six and 11 dry days later to determine whether the sites amended with organic matter retained water more effectively than the others. It was therefore necessary to carry out the test in March, when rainfall events were expected to be spaced two to three weeks apart. The difficulties of predicting rainfall in order to carry out this type of experiment highlights the difficulties farmers face when attempting to predict the rainfall crops will receive, and therefore what practices to carry out.

The targeting of organic inputs to compound rather than bush farms in West Africa has been described (Prothero 1957; Manlay *et al.* 2002) and was confirmed by farmers. Accordingly 30 *sanbanni* sites were chosen to act as a proxy for soils to which compost had been applied and thus contained a high content of organic matter, and 30 *puuni* sites represented those without compost. Visual assessment of SOM content based on looser texture and darker colour (Coyne 1999; Fullen and Catt 2004) guided selection of specific patches of soil within these zones. This mode of site selection is admittedly subjective and does not guarantee to select soils with an organic matter input level similar to that obtained from applying compost at the levels applied in the farm. However as the test was necessarily carried out in March these were the only sites available to replicate additions of organic matter. Selecting sites which had been applied with compost the previous cropping season would not give a meaningful comparison as much of that organic matter would have been mineralized, immobilised or compacted.

An additional risk with sampling village sites is that they are more susceptible to additions of water from sources other than rain - washing water and animal urine especially.

The first samples were taken the day after rain fell on 17th March 2010. A pipe of 15mm diameter was driven 15cm into the soil at each of the 60 sampling sites and the soil removed was placed into an aluminium sample container, sealed with a plastic cap and weighed within three hours of sampling. The position of the sample site was marked and GPS coordinates taken. The second samples were taken six days after rain, 30 centimetres away from the first. A week after rain would have been preferable because it would correspond more closely to the length of time that farmers and extension officers claimed maize took to suffer water stress. However, because rain threatened again, six days was chosen to ensure a data set. Cloudy, hazy weather meant minimal evaporation took place between the first and second sampling dates, so a third date was added 11 days after the first rainfall. There was only one replicate within sites as the aim was to examine how an individual patch of soil retained water, not an average area. Even had it been desirable, practical constraints prevented replication - it would have been impossibly time-consuming for 60 sites, and water would have been lost from the soil during homogenisation. Samples were dried at 105°c for 24 hours in a Wagtech oven at the University of Development Studies, Nyankpala, and weighed again using the same scales as used in the field to determine moisture content as a percentage of wet soil weight. Changes in this value and percentage water loss were calculated. Bulk density could also be calculated from this data as the volume of the core sample was known to be $2.65 \times 10^{-5} m^3$. Data were non-normally distributed so a non-parametric Kruskall-Wallis test between the sets of samples determined whether there was a significant difference between the *sanbanni* soils that were amended with organic matter and the *puuni* soils that were not in terms of their water content after rain and percentage change in water content.

4.14 Questionnaires

Structured questionnaires were used at later stages of the research process. These facilitated the collection of more targeted information than the semi-structured interviews used at the early, exploratory stages.

4.14.1 2010 questionnaire

After harvesting, farmers participated in a survey using the questionnaire shown in Appendix 8. The aim of this questionnaire was to evaluate the soil fertility and transport processes farmers had tested over the 2010 season, follow up any unexplained results, quantify some of the trends the researcher had noted throughout the course of the season through participant observation and, most importantly, to obtain farmers' opinions on which capitals had in fact been necessary for each transport and SFM strategy.

The questionnaire, which again took place on the farm, comprised three parts. The first dealt with *benzirra* and modes of transport. The second examined SFM and the third involved questions specific to each farmer and their farm. In the third section the farm map constructed in early 2010 in the first interview was used to identify factors contributing to better or worse yields and allowed farmers to explain the reasons for any changes they had made to their planned fertilisation strategy for 2010.

Several variables were computed from the questionnaire responses. Fertiliser application rates were calculated from the answers to questions 14 and 15 which asked how many bags of compound and ammonia fertiliser each farmer had applied to the experimental site as well as to other fields and how many bags had been bought or borrowed.

Farmers ranked all the *benzirra* they had used and their top three SFM strategies. These were holistic rankings, and farmers' qualitative explanations of their decision making processes revealed they took into account the efficacy, expense and availability of different strategies. However, differences in the extent to which individuals were able to rationalise their reasoning meant that it was less meaningful to ask them to be more discriminate in the way they differentiated between their chosen strategies, for example using a separate score based on each of these criteria. It was more accurate to recognise and report these explanatory characteristics as qualitative data. These rankings were computed into a single weighted ranking in the following way:

Points were allocated to each SFM strategy. Those farmers ranked as 'best' were awarded three points, the second two and the third one. The cumulative scores for each technique were then divided by the number of farmers using them to obtain a mean score per user.

Whereas all farmers selected their favourite three SFM techniques, many farmers used different combinations of *benzirra* and many more farmers used the donkey than any other form of transport. It was therefore not possible to allocate points to *benzirra* in the same way as SFM techniques. Instead, farmers ranked each vehicle and the percentage of users naming each as 'best' was calculated.

Farmers stated the advantages and disadvantages of each *benzirigu*. Their opinions on the necessary capitals for using each *benzirigu* were obtained using the open question 'what do you need to solve those disadvantages?' Very similar answers were grouped and responses reported as the percentage of farmers that used each *benzirigu* making each statement.

A similar question was asked in order to obtain farmers' opinions on which capitals were necessary for use of different SFM strategies. This question was initially asked as 'do you need anything to be able to practice that Soil Fertility Management strategy?' This wording was chosen in order to give the farmers the option of saying that they had all the resources necessary to be able to practice that strategy. However the majority of farmers answered this question with 'yes, I need something'. When asked 'what, then, do you need?' many were unable to state the specific tool or resource they lacked. It was evident that the claim of insufficient resources was coloured by many farmers' optimistic but somewhat misguided perception of the role of the researcher; a common response to the follow-up question 'what, then, do you need?' was 'anything you can give me'. It was therefore explained to farmers that the question was not an offer, and some farmers were then able to give a specific response. An immediate conclusion was that this problem had a linguistic root, lying in the translation of the question and in particular with the role of the word '*bora*' which is used for 'want', 'need' and 'like'. Accordingly the phrase '*A bora benshaγγo ka a ......*' ('do you want/need / like anything so that you.....') was taken to mean 'what do you *want*/would you *like* so that you.......' rather than 'what do you *need* so that you...'. Many farmers also made the unjustified assumption that the question was 'what do you need/want like *me to give you* so that you....' This was evidently because the donkey cart had been provided by the researcher so there was a hope that other resources would follow. The question was reworded as 'are there any resources or tools that are necessary to allow you to ....' (*'nema sheli bieni ka a bora ka a....'*). However this was still unsuccessful. Farmers still responded with answers like 'yes, there are. Any you would like to give me.' We also tried asking 'what do you need so that you.... ('*bo ka a bora ka a*....') first, rather than preceding it with 'do you need anything....'. However many farmers found it difficult to answer this question at all or merely gave the answer '*nn bora benshaγγo*' ('I need/want/ like something'). It was necessary to conclude that this phenomenon was a result of the meeting between the gift-exchange aspect of Dagbanli culture and the power relations between rich white foreign researchers and villagers who represent themselves as poor receivers. The only solution was to note it, account for it in the results and see it as a further layer of qualitative data that again, whilst it confounded the ability to perform statistical analysis, gave insight into the underlying mechanisms surrounding access routes to the capitals required to perform the various SFM and IMT strategies. Despite this quandary, data from this question were collected and reported, although it may represent more the farmers' perception of the role of the researcher than the capital requirements of the SFM strategy in question.

4.14.2 2011 questionnaire

In 2011 another questionnaire, shown in Appendix 9, was designed to assess farmers' ongoing opinions on the different SFM strategies and forms of transport after using them for a year. It was also necessary to clarify some issues which had arisen during data analysis between December 2010 and February 2011, mainly to do with the differences between cattle and donkeys. This shorter questionnaire took place in the home and involved only 34 farmers as it was evident data were becoming saturated (Glaser and Strauss 1967) and participants fatigued.

Major strengths of this project lie in its large sample size, the combination of qualitative and quantitative data and the emphasis laid upon participant observation during fieldwork. The iterative methodology meant that methods could be constantly adjusted to address new and relevant concerns that arose throughout the field work period. This approach went some way towards ensuring that, although the study was not intended to be entirely participant led, the questions posed and results obtained were relevant to participants' livelihoods. Simultaneous analysis of the qualitative and quantitative data, structured by the themes identified in the results, permits their synthesis to present a holistic assessment of each facet of the research problem. Accordingly, the following two chapters present quantitative results relating to each research question. Where necessary, qualitative results have been interwoven to explain them. Chapter five deals with the carriage of compost to the farm and Chapter six examines the effect of the compost once it was used.

Carrying compost with bicycles and a hired group donkey in Yilikpani

Chapter Five

Intermediate transport

5.1 Chapter structure

While there is a considerable literature examining the way capital acts through SFM to influence farmers' livelihoods, less attention has been paid to the role of capital in smallholders' transport strategies. The pilot project preceding this thesis identified that transport was the primary mechanism through which the capital endowments of the farmers in this study affect the fertility of their soils, and Chapters two and three confirmed that the high labour costs of carriage were a major theme in the general literature. This chapter explores the details of how that mechanism works, examining data collected on the modes of transport Dagomba farmers used to carry compost to the farm. It addresses the first research question, 'What is the best way to carry compost to the farm and what are the capital requirements of this strategy?' Throughout the analysis the third question, 'Which types of capital and systems of capital use can best facilitate effective SFM in Dagbon?' is touched upon. The results indicate that when sufficient financial capital is available to individuals within the community, their purchase of large *benzirra* facilitates the economy of sharing and reciprocity that characterise the traditional system of capital organisation. The participatory system that uses social capital at the community or group scale becomes more important when overall levels of financial capital are lower.

The chapter begins by comparing the capacity of each of the six *benzirra* farmers tested and their opinions about the relative benefits of each. A consideration of the capital requirements of each mode defines the relationship between the capitalist, traditional and participatory systems, confirming the scales at which they act in the study villages. Comparing the two animal-drawn modes of transport reveals the importance of timely practice as a mechanism through which capital limitation worked. Interactions between the various capital use systems are illustrated further through examinations of how individuals' capital endowments affected how much compost they could carry, the synergies that occur between different modes of transport and farmers' perceptions of the capital requirements of the various modes. A final theme that emerges from this chapter is the importance of having access to a range of liquid and fungible capitals and systems of their use.

5.2 Efficiencies of different modes of transport

Farmers who participated in the project used one or more of six *benzirra* (headpan, bicycle, wheelbarrow, truck, donkey cart and bullock cart) to carry compost to their maize farms, recording the time each carrying session began and finished, how many people helped and the number of trips they made. Weighing nine compost samples revealed the extreme variety of densities between them (table 5.1) and led to the decision to display results in terms of volume rather than weight. This expression of quantity is also more relevant to farmers, who have no weighing scales.

Table 5.1 Densities of different types of compost

Compost	**Density (kg/m^3)**
Dry cow manure	500.0
Dry decomposed rice straw, small ruminant manure, cow manure and the compacted floor of the livestock enclosure	611.1
Dry small ruminant manure, rice bran and compacted floor	629.6
Dry decomposed rice straw and small ruminant manure	814.8
Slightly damp rice straw and small ruminant manure	859.3
Moist rice straw and small ruminant manure	896.3
Wet cow manure (1)	981.5
Wet cow manure (2)	1296.3
Well rotted cow manure	1666.7
Mean	**903.7**

These data were combined with the distance to each farm to calculate volume carried per person-hour, per person-hour*kilometre and per 'ideal' person-hour*kilometre, as described in Chapter four and Appendix 4.

Many farmers used each mode of transport more than once to carry all their compost to the farm. Time spent carrying and the amount of compost carried was recorded for each of those sessions, so a larger number of data points was available (N=271) if data from each session were used than if data were totalled for each farmer's use of a mode of transport within a farm (N=145). The range of values of volume carried per person-hour for each mode of transport is shown for both of those data sets in figures 5.1 and 5.2.

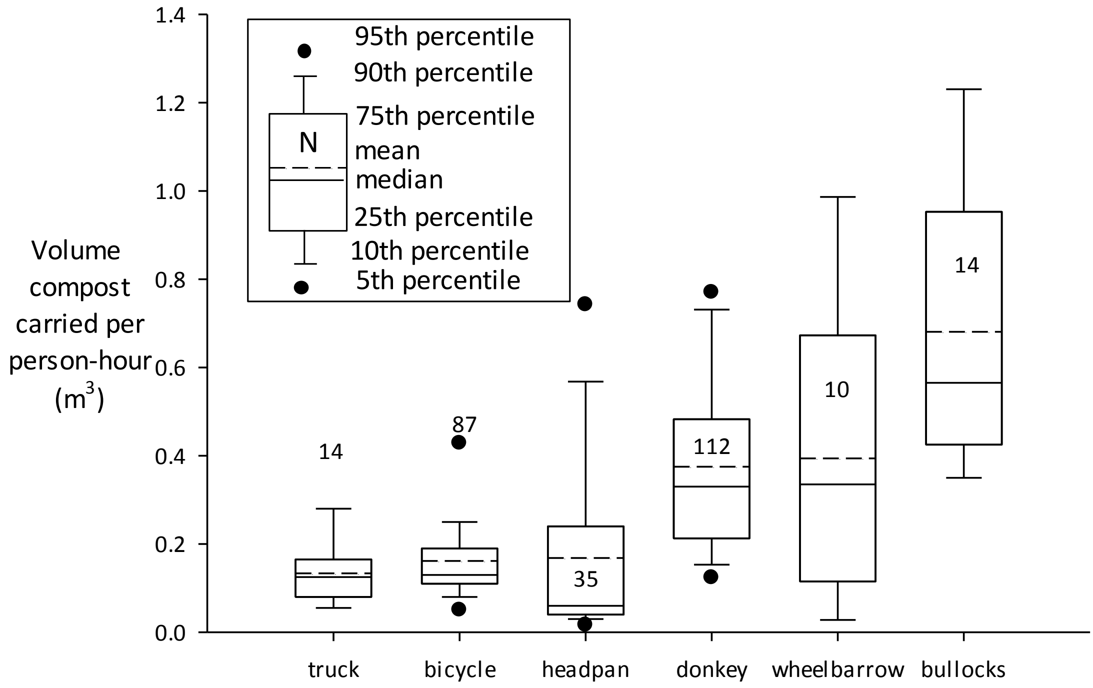

Figure 5.1 Volume of compost carried per person-hour by each mode of transport.
Notes: Each data point is one carrying session, N=Number of cases

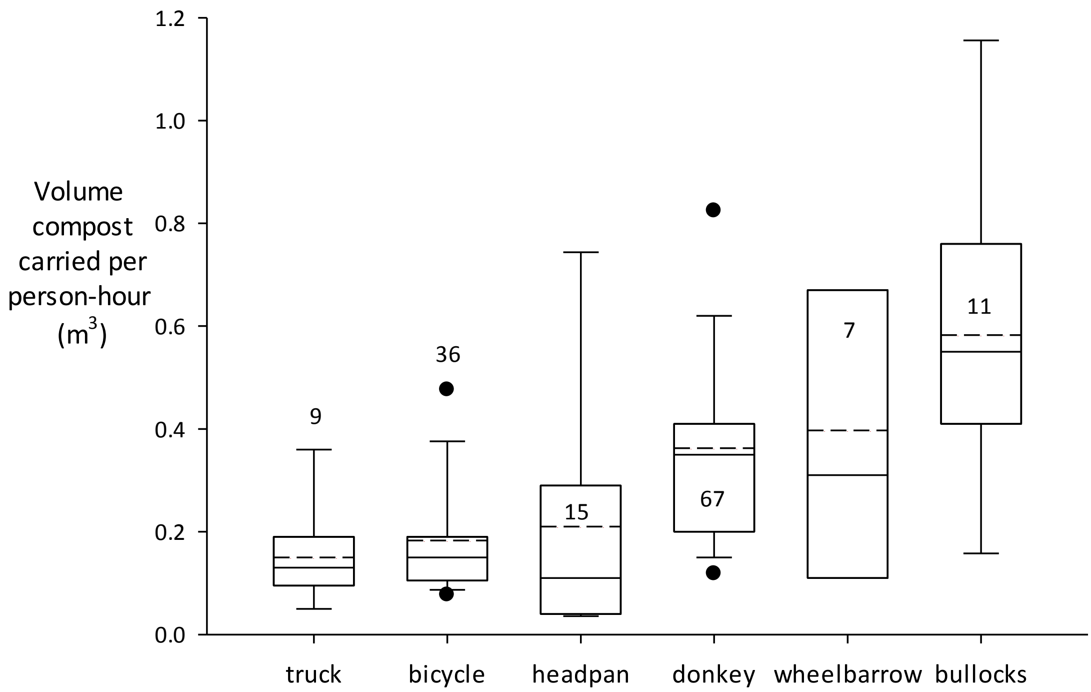

Figure 5.2 Volume of compost carried per person-hour by each mode of transport.
Note: Each data point is the total of all carrying sessions to one farm. Key as figure 5.1.

Neither set was normally distributed and non-parametric Kruskall-Wallis tests found that the mean volume of compost carried to the farm by each mode of transport was significantly different for per-session ($H=111.986$, $p<0.01$) and per-farm ($H=44.3$, $p<0.01$) datasets.

Both figure 5.1 and 5.2 show that the bullock cart carried the highest mean volume of compost, approximately 0.6 m^3/person-hour, followed by the wheelbarrow and then the donkey cart at around 0.4 m^3/person-hour. Headpans, bicycles and hand trucks all performed similarly poorly, carrying close to 0.2 m^3/person-hour.

Unsurprisingly, the larger animal-drawn *benzirra* carried significantly more compost than most of the smaller *benzirra* that relied on human labour. Even though bicycles travel much more quickly (up to 10 km/h) than donkey and bullock carts (3-6km/h), they could not compete with them in terms of volume carried per person-hour. Animal power allows the draft of large volume carts, reducing the number of people involved. The volume of these carts was enough to outcompete the speed of the bicycle, so *benzirigu* volume is more important than speed in facilitating carriage of more compost per person-hour. As will be confirmed shortly, much financial capital is required both for the cart and the animals that provide this rapid labour, and so that is more important than human capital in facilitating more time-efficient compost carriage.

The wheelbarrow performed surprisingly well considering its low volume. However the large error box indicates the low number and high variability of data for this data set as only six farmers used the wheelbarrow in 10 carrying sessions. This low number of replications meant that any high value will have a large effect on the mean, and indeed one value in the data set was much higher than the others, 1.02 m^3/person-hour compared to the other values which all fell into the range 0.02-0.68 m^3/person-hour. There were two possible reasons for such high values. Firstly, the wheelbarrow was identified in interviews as particularly 'tiring' requiring a lot of 'effort' (table 5.4). Thus it may be that only particularly energetic and dedicated individuals chose, or were physically able, to use it and this would increase the values. One farmer joked that he had chosen to use the wheelbarrow for exercise and a common complaint was that it hurt farmers' arms to use it. A second reason for high values for the wheelbarrow was that four of the seven farmers who used it carried compost to the *sanbanni* farm, hence why it carried a high volume of compost per person-hour. These observations and the low number of farmers opting to test it indicate that the wheelbarrow may be more appropriate for carrying compost to the *sanbanni* rather than the *puuni* farm and for spreading it around the *puuni* once it had been dumped there, as practiced by the two wheelbarrow owners in Zaazi and one in Ypilgu.

To test this idea, the data were split into two sets, one for farms up to 150m from the source of compost, representing the *sanbanni* farms in the sample, and one for all the others. Because there were fewer *sanbanni* farms in the sample, the per-session rather than the per-farm data sets were used so that there were enough observations to make legible graphs. Figure 5.3 and 5.4 show the data for farms within and over 150m from the site of compost.

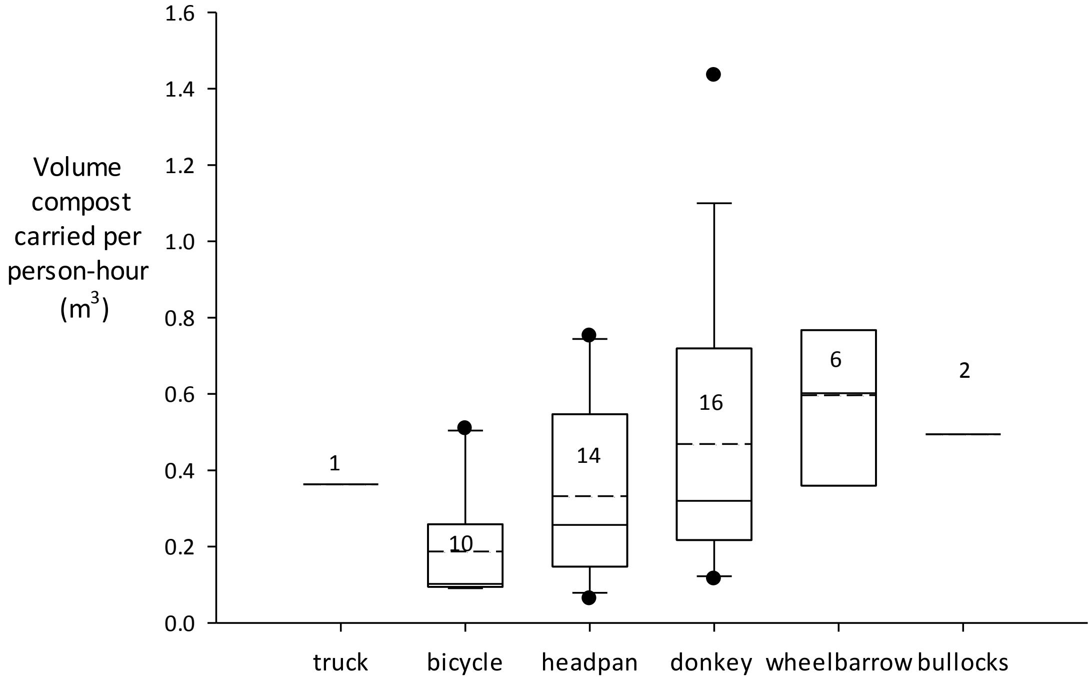

Figure 5.3 Volume of compost carried per person-hour by each mode of transport for farms less than 150m from the compost source.
Note: Each data point is one carrying session. Key as figure 5.1.

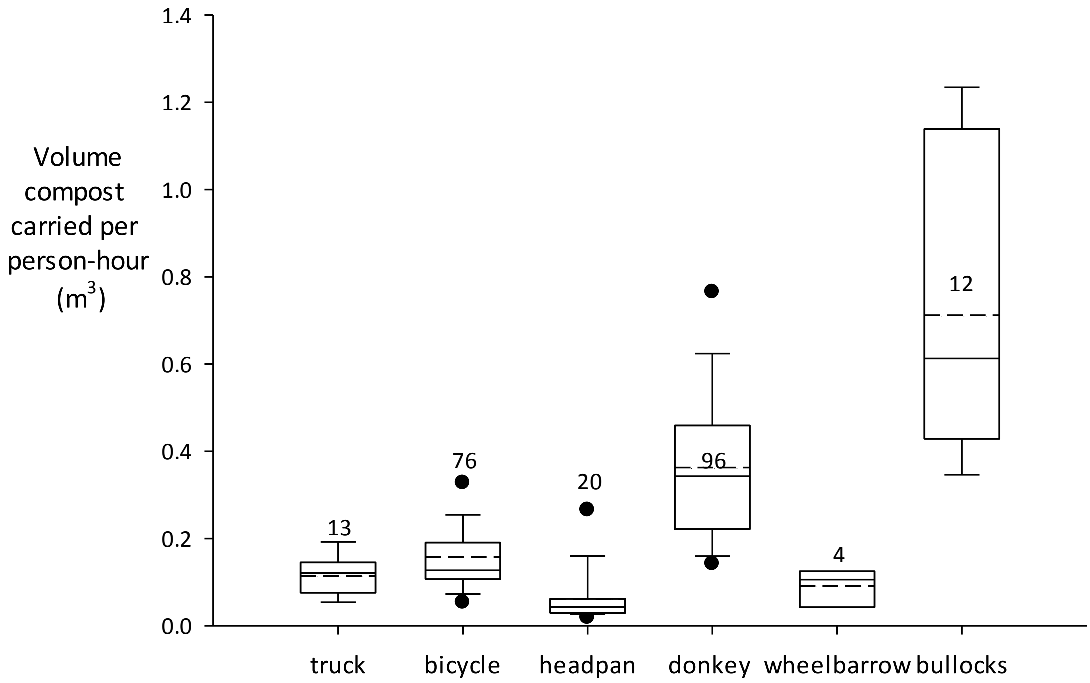

Figure 5.4 Volume of compost carried per person-hour by each mode of transport for farms more than 150m from the compost source.
Note: Each data point is one carrying session. Key as figure 5.1.

The results support the hypothesis that the wheelbarrow may be better for closer farms. For farms further away, although the forms of transport that rely mainly on human capital become less competitive in comparison to the animal-drawn *benzirra*, the bicycle is better able to compete due to its speed.

As described in Chapter four, this variable distance to different farms is one of two factors that may have acted to confound the results when they were expressed in terms of the volume of compost carried per person-hour. The other factor is that different farmers used different numbers of people to operate each *benzirigu,* not all of whom put in an equal amount of effort, making the unit of 'person-hour' less meaningful. To control for these variables the statistic 'volume carried per person-hour' was recomputed into two new variables, 'volume of compost carried per person-hour*kilometre' and 'volume of compost carried per 'ideal' person-hour*kilometre'. This had the effect of comparing the effectiveness of the forms of transport as if they were carrying compost to farms of equal distance using equal numbers of people. As expected, figures 5.5 and 5.6 show that when distance to farm was accounted for the mean volume carried per person-hour was lower for the wheelbarrow as it had primarily been used to carry compost to *sanbanni* farms.

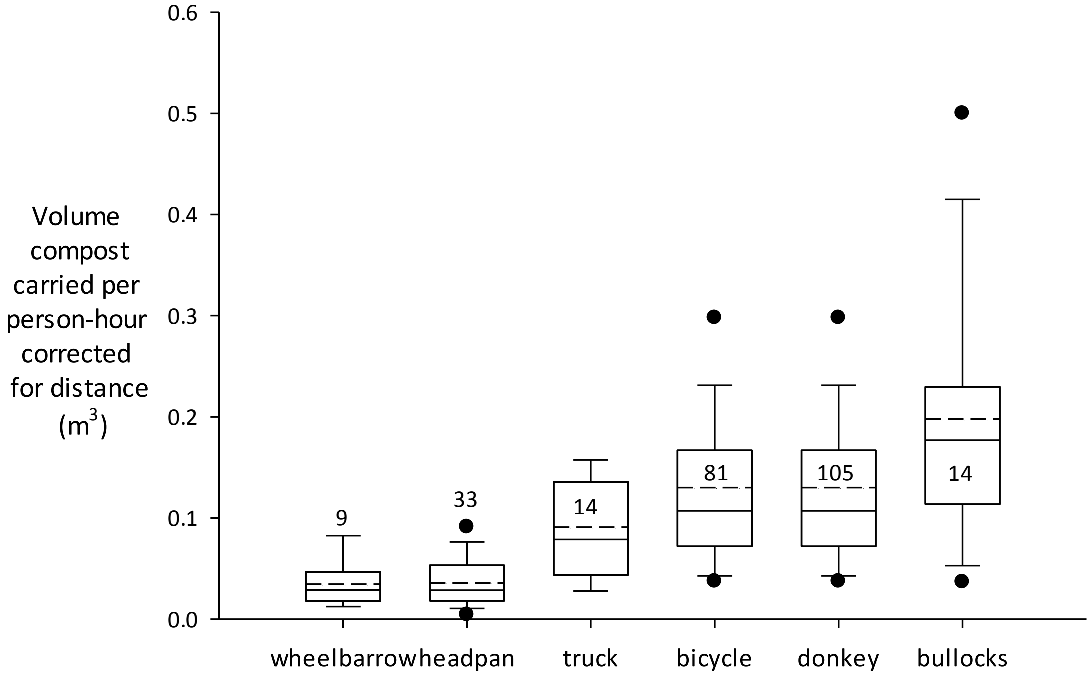

Figure 5.5 Volume compost carried per person-hour corrected for distance.
Note: Each data point is one carrying session. Key as figure 5.1.

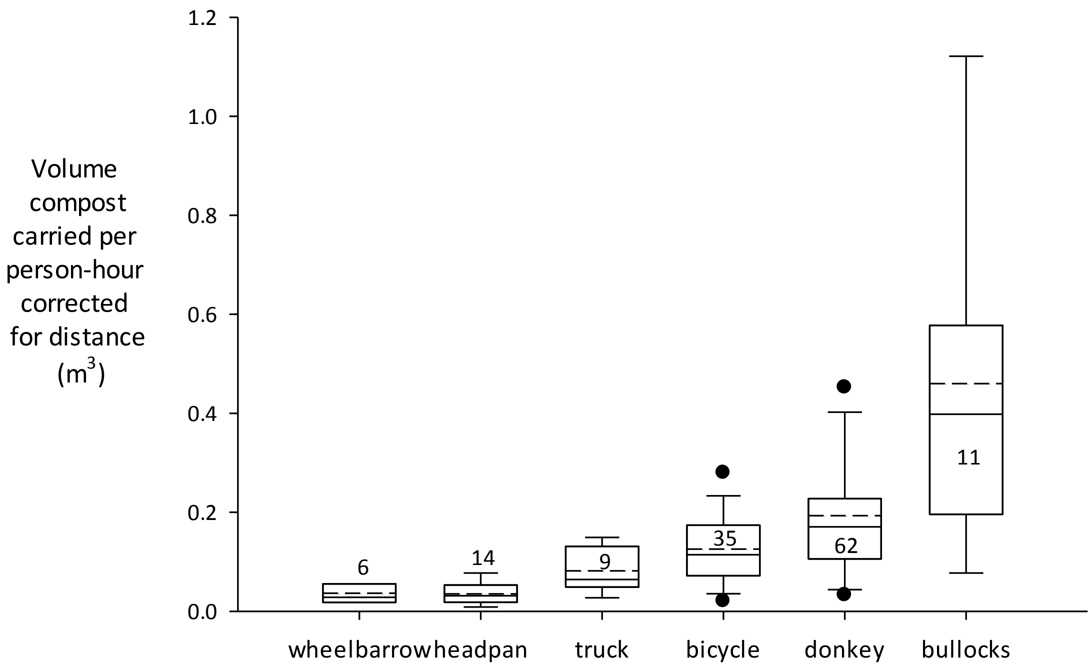

Figure 5.6 Volume compost carried per person-hour corrected for distance.
Note: Each data point is the total of all carrying sessions to one farm. Key as figure 5.1.

Due to the effort involved in its use, the slow wheelbarrow is only appropriate for carrying compost to *sanbanni* backyard farms and spreading compost already carried to the *puuni* bush farms.

Headloading and truck use were similarly inefficient due to their slow speed and high human capital requirement – the *trocko* is especially inappropriate as bagging compost for loading onto it could take up to half an hour, adding to the high amount of labour required to pull it.

The bicycle became more competitive when distance was accounted for because it was much faster than the other human powered *benzirra* and therefore, as illustrated by figures 5.3 and 5.4, more appropriate for longer distances.

These data confirm that *benzirigu* volume - and thus the financial capital required to buy a larger *benzirigu* and draft animals - is still the most important influence on how much compost can be carried per person-hour. Attention is, however, drawn to the speed of the bicycle in improving its efficiency over longer distances.

When distance is taken into account the quantitative survey results reflect the farmers' choice of *benzirra*: figure 5.14 will show that the bicycle and donkey were the most used vehicles. This makes sense as farmers were likely to choose the *benzirra* they knew from experience and observation of others' practice (Walker *et al.* 1995) were easiest and most efficient to use. Qualitative data confirmed this: section 5.3 will show that one of the reasons farmers preferred the draft *benzirra* was the relatively low level of human effort they involved.

Substituting the actual number of people operating each *benzirigu* with the minimum numbers considered necessary did not alter the significance of the test results and more importantly did not alter the order of effectiveness of the *benzirra*. This indicates farmers usually did use close to the minimum number of people necessary for each *benzirigu*, and the variable 'volume carried per 'ideal' person-hour*kilometre' was not used after this finding was made.

The quantitative data examined here have shown that due to their higher capacity, and thus lower human labour requirement relative to volume carried, animal-drawn *benzirra* are most time- and labour-efficient for carrying compost (Starkey 1990). The wheelbarrow has its own specific role: transporting compost to the *sanbanni* farm. All these three are specialist tools for carriage of loose materials. *Tahali* and trucks are also for carriage - however trucks are designed for carrying solid objects which do not need to be bagged so are less appropriate for compost. Bicycles, and their pannier racks in particular, are not designed primarily for carriage of very heavy objects. Evidence for this in Dagbon is the local manufacture of steel reinforced parcel racks which some people, especially traders, attach to their bikes to facilitate transporting goods. Indeed, bicycles have only been used for work in the past twenty years; in 1988 Hoeck described them as primarily used for social purposes. This may be another reason why farmers prefer animal-drawn vehicles, despite the competitiveness of the bicycle over longer distances. The implication of the high capacity vehicles being specifically for carriage of heavy loose materials, like compost, is that as they require the expenditure of much financial capital few farmers are actually able to use the most appropriate vehicle. Nevertheless, the results of the 2010 survey, designed to obtain farmers' opinions on the *benzirra,* showed that the large capacity vehicles were popular as well as effective. Section 5.3 now turns to this questionnaire.

5.3 Farmers' preferences

The aim of the 2010 questionnaire was to elaborate further on what, besides high volume, was desirable in a *benzirigu,* and to begin to identify the capitals necessary to use different forms of transport. Section 5.2 focused mainly upon the technical characteristics of the various *benzirra* such as their capacity. This section shows that when evaluating the effectiveness of different *benzirra,* farmers considered technical attributes alongside issues of capital and ownership. To reiterate, the bullock cart and handtruck were hired by the researcher, although farmers used their own animals to pull the bullock cart. This describes a situation of individual capital accumulation, although, as will be seen shortly, bullock and cart ownership did provide an opportunity for this capitalist mode to articulate with the traditional mode of sharing and borrowing, thus facilitating what Ostrom (1996) called coproduction. That system of individual private capital ownership was seen again in farmers' use of their own bicycles, and it often combined with the traditional use of their household's labour when they headloaded in a group. In a representation of the participatory paradigm, the wheelbarrow and donkey cart were purchased by the researcher for members of the group of participant farmers to use free of charge. The fact that state ownership played no role in the experiment is in itself evidence of its limited relevance to this situation.

Farmers' preferences reflected the capacities of the *benzirra*. They were asked to rank the three vehicles they found most useful overall. Figure 5.7 shows the percentage of users of each vehicle who ranked it as best.

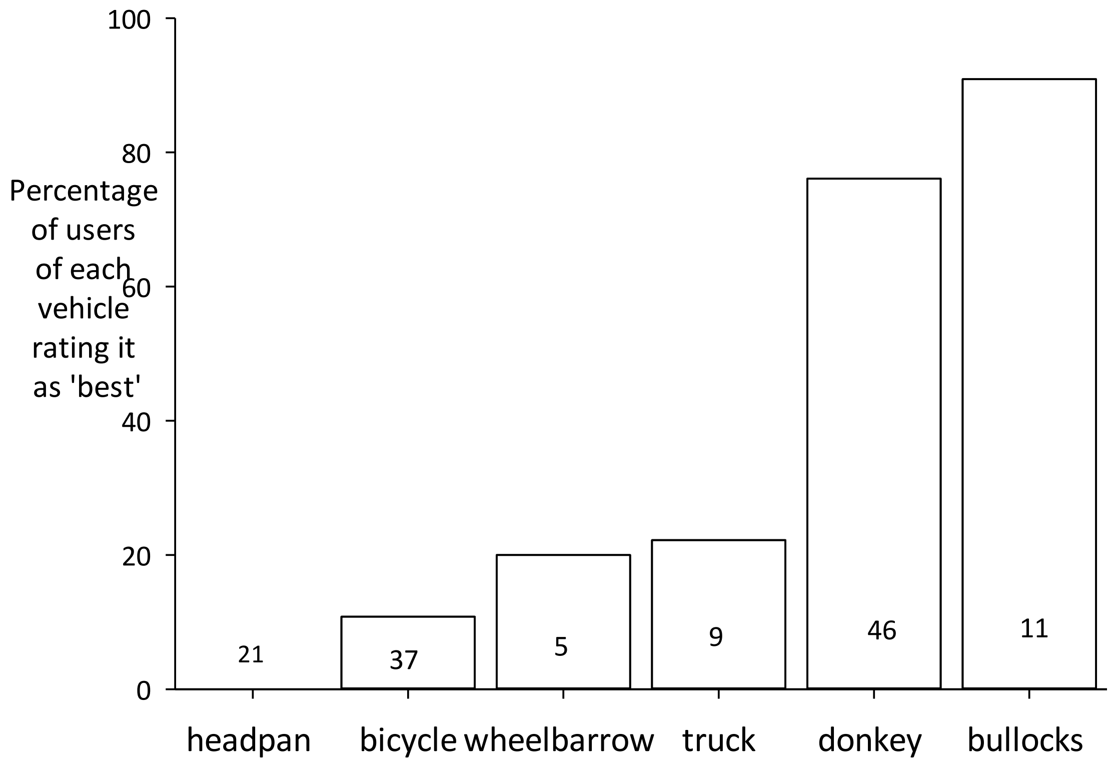

Figure. 5.7 Farmers' rankings of the different modes of transport
Note: N is indicated on bars

Farmers explained why they preferred bullocks over other modes of transport when they were asked to detail the advantages and disadvantages of each mode. At this point it should be reiterated that as the survey section of the results is approached, informed by qualitative data, there are no 'true' but only majority answers. There is no way to measure quantitatively the characteristics and capital requirements of each mode of transport. As users of the technology, the farmers were asked for their opinions both in survey and interview and this is triangulated with the researcher's participant observation to infer the most likely explanation. This proved fruitful as due to their long experience in this environment the farmers had a stock of 'indigenous knowledge' and their observations contributed many points participant observation had not independently identified. Thus, comment upon the quantitative results of the survey presented next also draws upon qualitative data from interview, conversation, participation and observation.

Table 5.2 shows that the main reason farmers most frequently ranked the bullock cart as their favourite form of transport in figure 5.7 was its large volume, reflecting the quantitative results displayed in figures 5.1 - 5.6.

Table 5.2 Named advantages of each mode of transport.

	Headpan	**Bicycle**	**Wheelbarrow**	**Truck**	**Donkey**	**Bullocks**
Generally helpful	*** (34.8%)	*** (27.0%)	**		**	
Large amount		*	*** (60.0%)	*** (66.7%)	*** (57.7%)	*** (80.0%)
Fast	*	**	**	**	**	*
Multipurpose		**	**	**		*
All that was available	*	*		**		
Used any time/ can work all day		*		**	*	
Little effort		**			**	
Can offload at any point		*				
Cheap		*				
Available anytime		**				
If donkey sick				**		
Few people					*	
Available in the community					*	

Notes: *=mentioned **=mentioned by more than 10% of users ***= mentioned by most people (% of people mentioned by).

As will be detailed further the main advantage of this high capacity was the speed with which large volumes of compost could then be carried to the farm. The fact that the most commonly selected benefit of the headpan and bicycle was just their general 'usefulness' shows that they had few advantages over the larger *benzirra*. Table 5.2 was generated from an open question: 'What were the benefits/advantages ('*anfani*') of this form of transport?' A common response if farmers felt the *benzirra* had few benefits was just to say 'it is useful because it helps carry compost'. Speed and multifunctionality were two other very frequently mentioned advantages. The bicycle in particular is used for many purposes, social as well as work-related, a reminder that compost carriage is just one of many necessary transport activities. The ability to work all day until tired was an advantage that will be returned to shortly; for now it should be noted that this was a property of the bicycle, truck and donkey cart.

It is interesting to note that although much of the qualitative evidence from farmer interviews emphasises the importance of financial capital, in this survey only one farmer mentioned that a *benzirigu* (in this case a bicycle) was cheap. This may be because in the experiment all the larger *benzirra* were free to the farmer in the first year as the researcher bought and hired them (except the cattle that farmers used to pull the hired bullock cart). In the second year, farmers in Ypilgu also paid a nominal 1GhC for the donkey cart. However, some farmers did hire their own *benzirra* both in 2010 and 2011 and had done so in other years. Those who were able to do so evidently felt the cost of hiring was affordable, considering the benefit they would derive from it. These farmers became more willing to pay as the market gradually played a more dominant role in their livelihood strategies - a trend which has been occurring over the past century in rural economies across the region (Guyer 1981; Dei 1992; Berry 1993; Vehnamaki 1999). Such willingness to pay will be examined in more depth in section 5.9 which considers the relative importance of hire markets and group ownership.

Farmers were also asked their views on the disadvantages of different forms of transport: ‘When you used this mode of transport what were the disadvantages/ problems *(‘yelimuɣirisili’*) with it?)

Table 5.3 Named disadvantages of each mode of transport.

	Headpan	Bicycle	Wheelbarrow	Truck	Donkey	Bullocks
Effort/ tiring	*** (47.8%)	**	*** (80.0%)	*** (44.4%)	*	
Equipment can get damaged		*** (73.0%)	**	**	**	*
Not owning one personally and having to borrow or hire it				**		*** (30.0%)
Feeding the animal					*** (15.4%)	
Slow	**	*			*	
Has a specific time for work	*					**
Illness/pregnancy prevents work	*				*	
Requires many people				**		*
Waiting for turn					**	
Carries a small amount	**	**				
Risk of injury	*	*				
Dirty	*					
Time conflict with other jobs e.g. ploughing	*					*
Can't get deep into the farm		*				
Tying a sack is difficult		*				
Needs equipment		*				
Difficult to steer					*	
If the road is bad it's hard					*	
Loading the cart with compost					*	
Feeding the driver					*	
Compost needs to be spread after dumping						*

Notes: *=mentioned **=mentioned by more than 10% of users ***= mentioned by more people than any other mode (% of people that mentioned it).

The disadvantage felt most keenly by the farmers was the physical effort involved in using the *benzirra* that relied on human rather than draft power. Even though many, especially those with much social capital, could supplement their own labour with that available in their households, this aspect of the traditional mode of production was not one that they relished. The propensity of wheeled *benzirra* to become damaged was also a commonly perceived problem, conceivably because this entailed the use of financial capital to fix them; thus, in the absence of cash accidents rendered such *benzirra* unusable.

Once again note the importance of *benzirigu* volume. The large capacity of the wheelbarrow, truck, donkey and bullocks was identified as beneficial in table 5.2, and this was confirmed in table 5.3 when 22% and 27.0% of people who used the bicycle and headpan named their small capacity as a major disadvantage.

5.4 Farmers' perceptions of capital requirements of individual benzirra

Having detailed the advantages and disadvantages they associated with each *benzirigu*, respondents were asked how they would overcome disadvantages and what they would need to do so. As this was an open question many farmers gave similar but not identical answers e.g. 'money' and 'sell farm produce to get money'. These similar answers have been grouped and the data are illustrated in figures 5.8-5.12. The most commonly named solutions for each form of transport and the capital it implicated are summarised in table 5.4. This analysis begins to link the sources of capital considered necessary for each vehicle and the scales at which they act to the four capital use systems and development ideologies that structure this work.

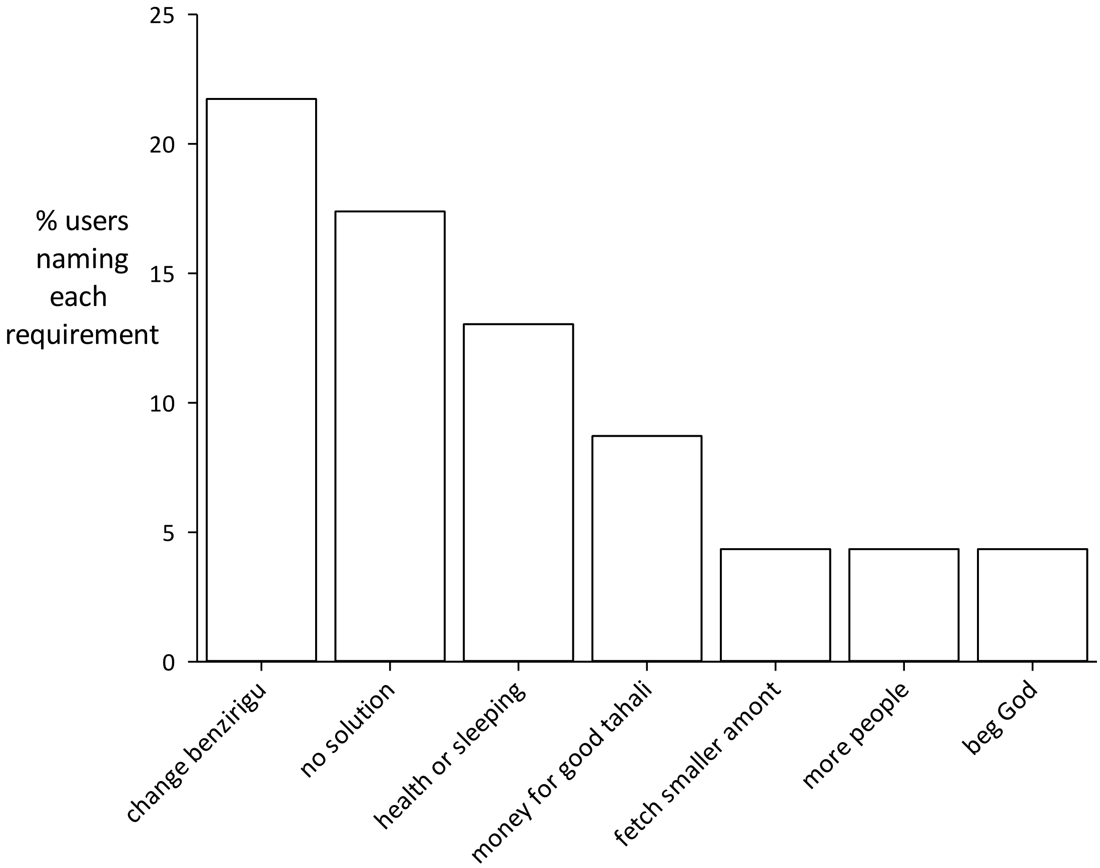

Figure 5.8 Perception of the 23 headpan users of its resource requirements.

When farmers were asked how they could solve the problems they encountered when using the headpan, the commonest responses were 'change *benzirigu*' and 'no solution'. The prevalence of these responses expresses dissatisfaction with this mode of carriage and inability to improve upon it. Human capital is the main resource necessary for head carriage. 'More people' was one solution named and indicates that those with social capital within their household were currently using it to access their households' labour within the traditional pattern of household reproduction.

A step up from head carriage is the bicycle.

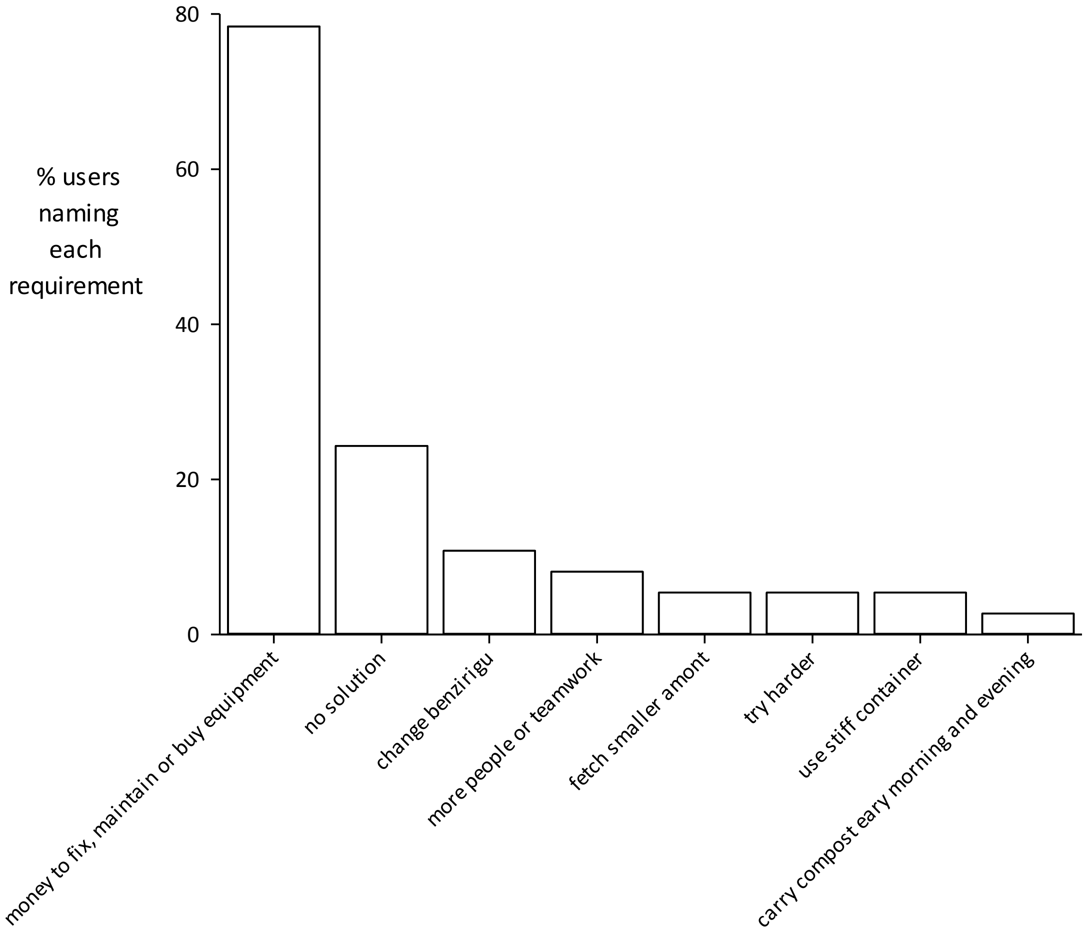

Figure 5.9 Perception of the 37 bicycle users of its resource requirements.

Here, the second and third most commonly suggested solutions were again ‘no solution’ and ‘change *benzirigu*’. However, in this case, the dissatisfaction these responses indicated is probably due to the overwhelming association of the bicycle with financial outlay: almost four fifths of responses referred to cash. This association had not been made so explicitly by farmers in other data beyond a few mentions in interviews of the cost of maintaining a broken bicycle. Indeed, bicycles cost much less than animal-drawn carts, hence why they are so common in Dagbon. However, this data indicates that cash cost *was* a central concern, highlighting the importance of triangulation. Human capital is also necessary to use bicycles, and a small proportion of responses advocating ‘more people’ indicates again that within the existing system of household reproduction individuals have access to others’ labour. Reflecting further dissatisfaction with modes of transport that rely on human labour, two responses focused on breaking up the individuals’ workload.

However there are advantages to the use of bicycles, hence why figure 5.14 will show that they were the second most commonly used vehicle. Spare parts for the two dominant models are widely available: bicycle ownership has reached a ‘critical mass’ in Dagbon, so providing maintenance services or supply of spare parts is profitable (Starkey *et al.* 2002). Bikes can also traverse the narrow sandy paths leading to farmers’ fields. Riverson and Carapetis (1991) describe the subsidised introduction of a bicycle trailer to Northern Ghana, an episode also related by an extension officer in the study site. However, in 2002 Porter noted that after the subsidy was removed the technology was abandoned. It may be that the bicycle with its pannier rack alone is capable of carrying much of what a farmer needs, making the extra expense and effort of pulling a trailer unwarranted.

As bikes involve a financial investment that individuals can and do afford, they are owned primarily as private goods within a capitalist market. However, their non-subtractable nature means they are not entirely excludable within the household context, and are thus easily shared and borrowed within the household, or indeed community, as part of the traditional system.

Farmers' suggested solutions for improving their use of the wheelbarrow indicate why it was a less suitable mode of transport. Equal numbers of people considered that the solutions to problems with wheelbarrow use were to fix the wheelbarrow, to change to another benzirigu, to have patience or to use painkillers. These responses show that there was again overall dissatisfaction with the reliance on an individual's human labour. With other vehicles, people typically overcame this by using social capital to enlist the human capital of those within their household into communal labour - the traditional solution to a labour bottleneck. However the nature of the wheelbarrow precludes groupwork, making it impossible to reduce the amount of human capital the individual farmer had to invest in its use. Equally, none chose to incorporate it into a working team.

As mentioned in Chapter three, wheelbarrows are most commonly owned by those who use them for paid work as there is a cash return of the investment. Indeed, wheelbarrows were owned in Ypilgu only by a mason and in Zaazi by a comparatively well off, educated, English speaker and by the facilitator. Wheelbarrows, like bicycles, can be used by those members of the owners' household who have sufficient social capital to borrow them: those engaged in the capitalist economy through their trade thus make the wheelbarrow available to others in their household through the traditional borrowing system. However, unlike bicycles, replacing broken wheelbarrow parts is difficult as the number of owners in rural areas has not increased to a 'critical mass'. This, alongside their higher cost, is the most likely explanation for why wheelbarrows are used less than headpans. Lower efficiency is an inadequate explanation: wheelbarrows, with almost double a headpan's capacity, are sometimes more efficient than headpans (figures 5.1–5.6).

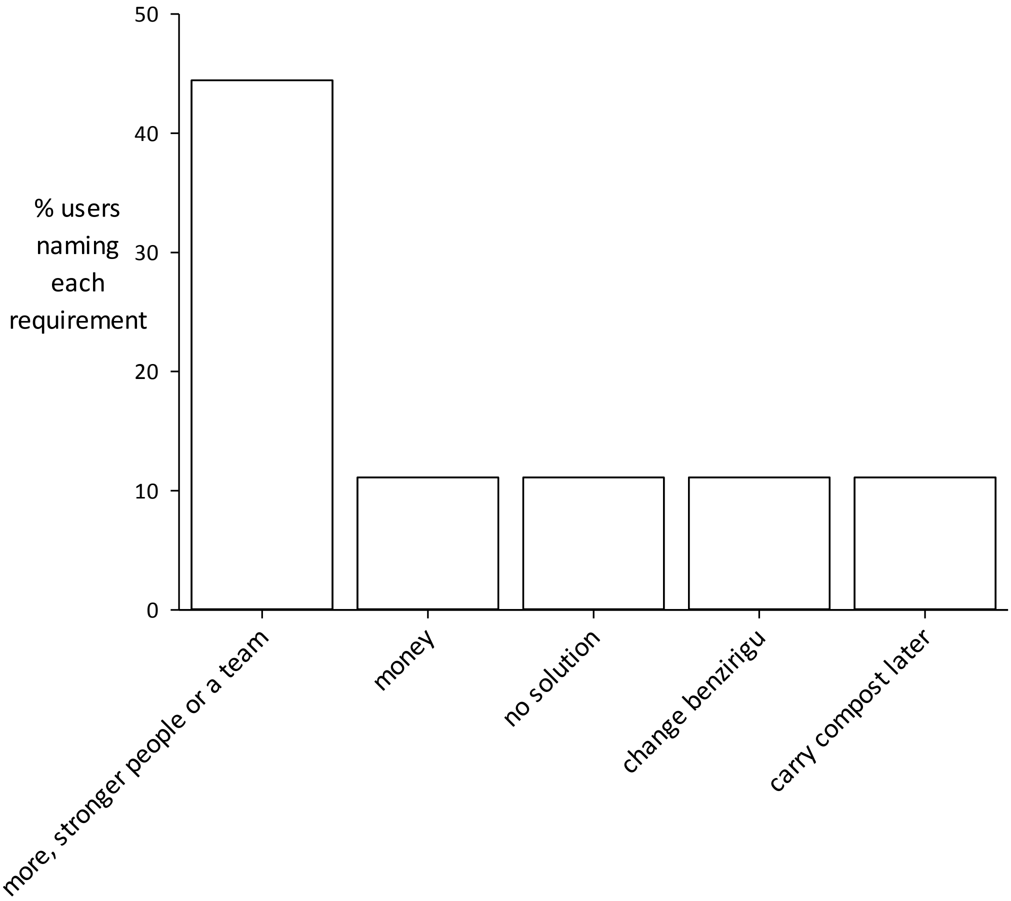

Figure 5.10 Perception of the 9 *trocko* users interviewed of its resource requirements.

The *trocko* requires at least four adults to push it. Users therefore draw on the human capital resources of kin and neighbours available to them at different scales through the traditional mode of production. This is recognised by the commonest response to use of the *trocko*, the need for more people to help with it. Such reliance on human capital may also be why answers expressing dissatisfaction with the truck ('no solution' and 'change *benzirigu*') are mentioned by the second greatest number of people. Financial capital is also necessary for the initial purchase and, if it is hired, the fee.

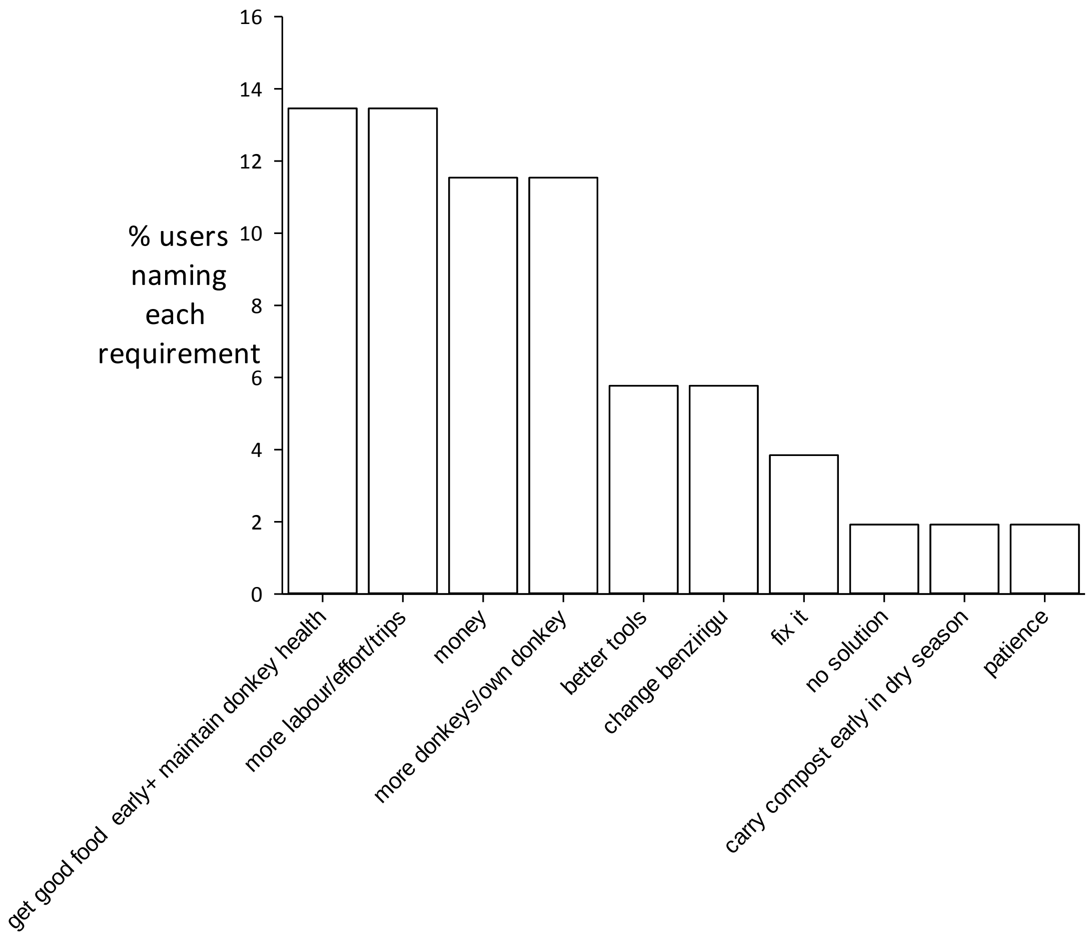

Figure 5.11 Perception of the 52 donkey cart users interviewed of its resource requirements.

The donkey owner's financial and human capitals are implicated by the need for its feed, the most commonly mention demand of this form of transport. However, access to more than one person's labour makes use of the cart much easier, so a donkey owner or user does need access to household human capital, indicated by the second commonest response, 'more labour'. This is facilitated by their individual social capital, for example by using the children to whom they have access.

The constraints upon purchase of a donkey cart are indicated by the fact that 'money' was the solution mentioned by the third greatest amount of people. Here it refers more to purchasing the donkey in the first place than hiring it. This is the key point - most farmers interviewed in 2010 felt that the purchase of a donkey, at 200 GhC, was prohibitively expensive, and this would be even truer for the 300 GhC truck.

However, by 2011 some farmers were beginning to overcome that financial capital barrier as they obtained livestock and carts. In Ypilgu in 2010, the NGO Heifer

International gave one farmer a donkey and cart which he later supplemented with a second cart bought with his own money. Another bought a female donkey and three farmers obtained bullock carts. In Zaazi the donkey group facilitator expressed the intention to buy a cart of his own, and three donkeys were already owned by two different villagers, of which one was sold out of the village in 2011. Examining the experiences of two of these people in further detail helps illustrate how increased financial capital has the potential to facilitate usufruct throughout the community.

In May 2011 Alhassan Suleimana of Dohinayilli in Ypilgu bought a female donkey and began saving to buy the cart. He felt a female was preferable, despite its weakness compared to a male, as he hoped to breed it. He therefore anticipated that within some years the benefits would outweigh the cost. Alhassan stated the primary aim of his purchase was not necessarily to hire the donkey's services for cash, but he offered the opinion that one's household members should pay at least a token amount towards draft as '(the owner) also struggled to get (the animals)'.

Similarly, when farmers in Zaazi queried what was to happen to the foal of the group donkey, Suleimana Ibrahim, the facilitator looking after them both and managing how they were used, replied that he wanted to buy a donkey cart with his own cash and use this and the young donkey to collect profit for private work, while the original adult female donkey would continue to belong to the group and work at the agreed rates. In a meeting in June 2011 the group agreed with this plan, stipulating that Suleimana would not be required to pay the group for the use of the younger donkey provided he kept to certain conditions. These were that should the group donkey become ill or the cart unfit for use he would substitute his own for it so a means of transport was always available to the group. In this sense the group abdicated much responsibility for the cart and the group functioning to Suleimana, making the functioning of the hitherto participatory group resemble an individual hire market situation, conceivably as a result of his social as well as financial capital. Acting as custodian of the group donkey also meant he was able to analyse the cost effectiveness of such an endeavour and evidently come to the decision that there was enough demand to make it worthwhile. Crucially, he was evidently richer than most of the group members and considered himself able to overcome the 200 GhC barrier of the expense of purchasing a donkey cart. Suleimana stated when proposing his plan that an additional donkey cart would help the community because it would provide a helpful service, and charging would be affordable because *'yoongo zaa nya* one family (all of (Zaazi) is one family) '. Although his assertion of altruistic motives (Bloch 1973; La Ferrara 2003) must be weighed against the financial advantage that would surely eventually accrue to him, his statement is evidence that he advocates supplementing the participatory system with one involving private ownership and associated hire alongside traditional usufruct at a community scale. Both Suleimana and Alhassan's stories show that the hire market becomes a viable possibility once the financial capital barrier has been overcome (Mpedi 2008). Such a market has definitely developed for donkey transport as well as ox traction in Northern Ghana (Bobobee 1999; Havard 1999; Hesse and Runge-Metzger 1999; Fernando and Starkey 2004).

The lack of financial capital constraining donkey cart ownership was of course also even more relevant to the larger and more expensive bullock cart, as shown in figure 5.12.

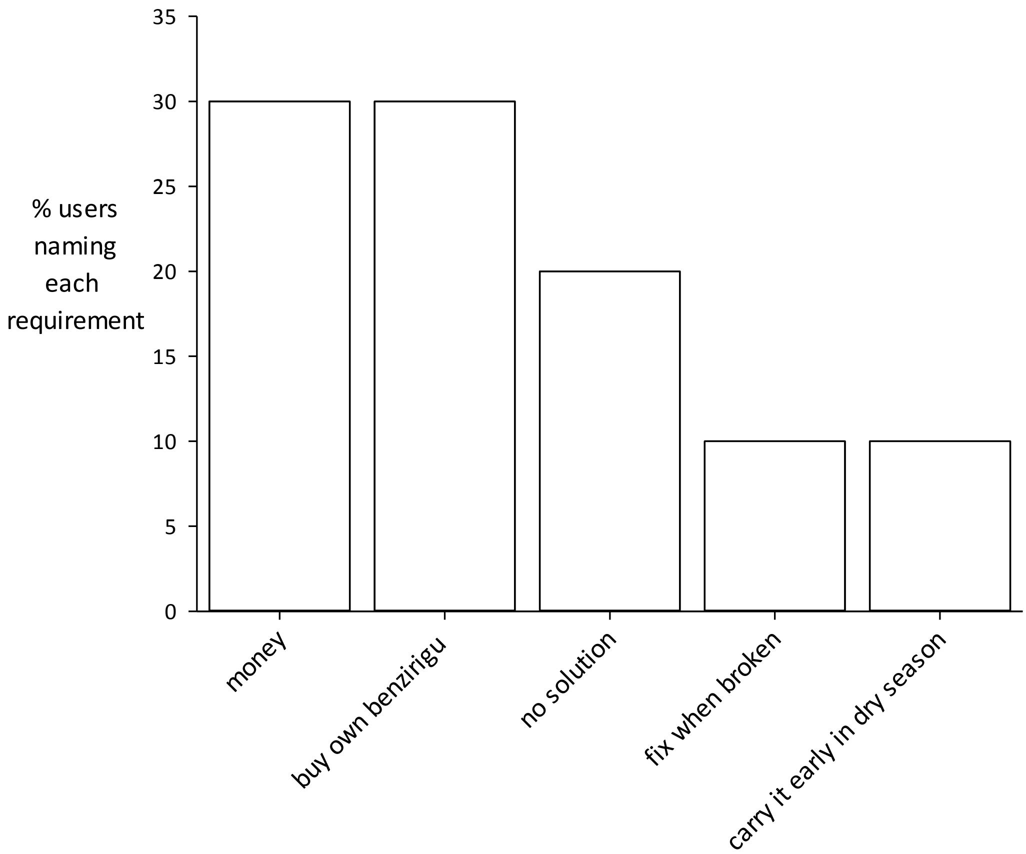

Figure 5.12 Perception of the 10 bullock cart users interviewed of its resource requirements.

It is interesting to consider these responses in relation to the respondents' finances. Many of them do in fact own bullocks, each valued at 400 GhC upwards, close to the combined cost of the donkey and cart. A bullock cart, depending on its size and state of repair, may start at 200 GhC. Money is indeed a barrier which many of the poorer farmers who own no cattle could not overcome. However when richer farmers say they 'cannot afford' to buy a cart it more accurately expresses that the risk in buying the cart is too great or they do not consider there to be a profitable hire market or use for it . Of the three farmers who obtained bullock carts in 2011, one had bought the cart for 200 GhC and one for 350. They speculated that the third owner received the cart as a gift, indicating that social capital played a role in its acquisition, although his reluctance to discuss this means it remains unverified.

Those who had purchased the carts evidently felt that the benefits of this asset would outweigh the costs. Bullocks are indeed important in the capitalist hire economy due to their low subtractability. They are not household property but have specific owners and are therefore at least partially excludable. For tillage, the bullocks, plough and driver service (commonly by a junior member of the bullock owner's household) are hired with cash (for 15 GhC/acre in 2010 and 20 GhC/acre in 2011), and those with their own bullocks can hire someone else's cart and use their own animals to pull it to the field. This is more commonly done to convey harvest to the house than for compost carriage, and can be paid for in produce.

Capitalist accumulation does not necessarily benefit only the capitalist. Especially if he is a landlord, part of the money he earns for the bullock's traction services may be reinvested back into the household for the benefit of all its members. The bullock driver may even receive a token amount. This confirms that although individual financial capital is essential for the use of bullocks, either as an owner or a hirer, and they are important to the rural capitalist economy, elements of the traditional economy - reciprocity, kinship and obligation - are inextricable from use of this commodity.

Indeed, individuals who bought bullock or donkey carts were motivated by the idea of using them within the household and lending them to peers as well as hiring them out. Of the eight farmers who owned or aimed to buy some type of cart, all but one said they planned both to carry household goods and to hire the cart out to others. Three stated the primary aim was household use, for example transporting harvest, water and firewood to the house and compost and yam stakes to the farm; two said their aim was hiring, and three said these functions were equally important for them. Of the six who already owned both a cart and an animal, three were observed lending it free of charge to their brothers, sons or neighbours to carry compost to their individual farms. In addition, both bullock cart owners and users cited cases in interview where private ownership had facilitated neighbourly usufruct. For example, Slimbongnaa lent his new bullock cart to some women from another village to carry firewood. He did not formally demand money from them but they gave him a token amount 'for kola' – a Ghanaian English phrase indicating a small amount in appreciation of what he had done for them. Yapalsinaayilli borrowed the bullock cart from their family members in Tarakpaa, the adjacent village, in 2010. In 2011 they did so again, but it got a puncture near the farm so they went to another new bullock cart owner in Ypilugu, Tampionlana, to borrow his new cart for that day. The transactions associated with private bullock cart bullock ownership thus reinforce the traditional economy performed at the household and community scales.

Table 5.4 summarises the solutions most commonly named by farmers in figures 5.8 - 5.12 as necessary for the use of each *benzirigu,* the type and source of capital each involves and the system of capital use this implies.

Table 5.4 Most named requirement for each *benzirigu*

Benzirigu	**Most named solution**	**Percentage practitioners naming it**	**Capital implicated**	**Source**	**Capital use system**
Headpan	No solution/ Health and sleep	39.1/ 13.0	None/ human	Individual/ household	Traditional
Bicycle	Money	78.4	Financial	Individual	Capitalist
Wheelbarrow	Fix it/ change *benzirigu*/ patience/ painkillers	25.0 each	Human/ Financial	Individual	Capitalist
Handcart	More people or a team	44.4	Human	Household	Traditional
Donkey	Feed	13.5	Financial/ Natural	Individual	Capitalist
Bullocks	Money or buy one's own	60.0	Financial	Individual	Capitalist

Farmers perceived a mixture of financial and human capital necessary to solve problems associated with the use of most *benzirra*. Overall, these results indicate dissatisfaction with the *benzirra* relying predominantly on human capital, but a lack of financial capital with which to solve this problem or change *benzirra*. A notable point is that it was difficult to identify one particular capital necessary to solve the problems associated with each *benzirigu*: in the case of the wheelbarrow, for example, none of the four problems identified appeared to be of greater significance than another, and many needs, for example donkey feed, require more than one capital. Table 5.4 is thus not intended as a definitive description but more an indication of the situation: it is important for farmers to have access to a range of capital systems rather than just the most effective. Section 5.5 can now consolidate how these systems interact in the study communities.

5.5 Capitals and paradigms necessary to use each *benzirigu*

Most of the capitals that participant farmers employed to gain access to *benzirra* were located at the individual and household scales associated with both the capitalist and traditional systems. The group donkey, organised at the community scale connected to participation, is an exception.

5.5.1 Traditional human capital

To farmers' chagrin, human capital was still an integral, although unpopular, element of the traditional system that most of them were using to carry their compost. Table 5.4 confirmed that the low capacity and the large amount of effort required to operate the *benzirra* relying on human labour were undesirable qualities. This was especially so when they had to use their individual human capital with the wheelbarrow, of which there was only one, preventing the group work integral to African farm systems (Swindell 1985; Upton 1987; Grigg 1995). Social capital was used to access household and community human capital in order to solve this problem; more people, labour or teamwork were the most commonly mentioned solutions for the truck and the fourth most commonly named for the bicycle. Landlords in particular use household labour, and labour from neighbouring houses was also occasionally contributed, especially in the case of the *trocko*, depending on how far the farm owner's social capital extended. Yet although they were widely used, dissatisfaction with these systems was indicated by the prevalence of the responses ‘there is no solution’ or ’change to another *benzirigu*’, the two most common answers for the headpan, the second and third commonest for the bicycle and the third and fourth for the truck.

Another linked characteristic was the poor quality of the physical capital. This is shown by the 73% of people who mentioned the propensity of the bicycle to ‘spoil’ and the incidence of ‘carry smaller amount of compost’ as a solution to the problems of the bike and headpan. People perceived that this poor quality equipment necessitated maintenance and replacement, both requiring financial capital. In the absence of financial capital the only solution is to have more people carrying a smaller amount each; the individual’s social capital again accessing household human capital and thereby acting as a substitute for financial capital. This reliance on human capital (Guyer 1981) was unpopular with those junior household members who actually had to carry the compost. Unfortunately for them, section 5.7 will show that it was common: the characteristic of farmers that correlates most strongly with the total amount of compost they carried was their access to labour. When asked who helped them on the farm all farmers mentioned family members, the majority of whom lived in their household, resounding with Kipo’s (1997) description of Dagomba labour trends and confirming that in 2010 most relied on the small capacity, labour intensive *benzirra* to carry their compost. Other proxies for wealth - animal ownership, access to bullocks and *benzirigu* ownership - are also poorly correlated with total amount of compost carried and none are related to higher amounts of compost carried per person-hour*kilometre. So although farmers named individual financial capital as necessary for the use of bullocks, donkeys, bicycles and trucks, in 2010 no smallholder actually had enough money to use them regularly enough to raise their overall efficiencies and were thus restricted to the use of headpans and bicycles more frequently than they wished.

5.5.2 Individual accumulation of financial capital for (large) *benzirra* and its interaction with the traditional economy

The prevalence of financial capital in table 5.4 prompts closer examination of figures 5.8 to 5.12 to reveal that money was the first, second or third most commonly mentioned requirement for all *benzirra* except the headpan.

When it came to the larger animal-drawn *benzirra* that carried compost most effectively, the financial capital necessary to hire and buy them was also located in an individual farm owner's pocket, implicating a system of individual capital accumulation and market hire. However, here the capitalist system overlapped with the traditional in a pattern to be repeated throughout the results. If a richer individual in a household - usually the landlord or an older son of his - gained access to a draft *benzirigu*, others were often able to use it on the basis of social capital derived from seniority or kinship, thus avoiding the need to expend financial capital themselves. Examples of this were given in section 5.4. Interview data from 2011 shown in figure 5.13 indicates that it was common practice in the case of bullocks: when asked, 71% of respondents indicated that if they treated them well, farmers were usually allowed free access to household members' bullocks after the owner had finished using them, often explained by way of statements like 'it is for all of us in the house'.

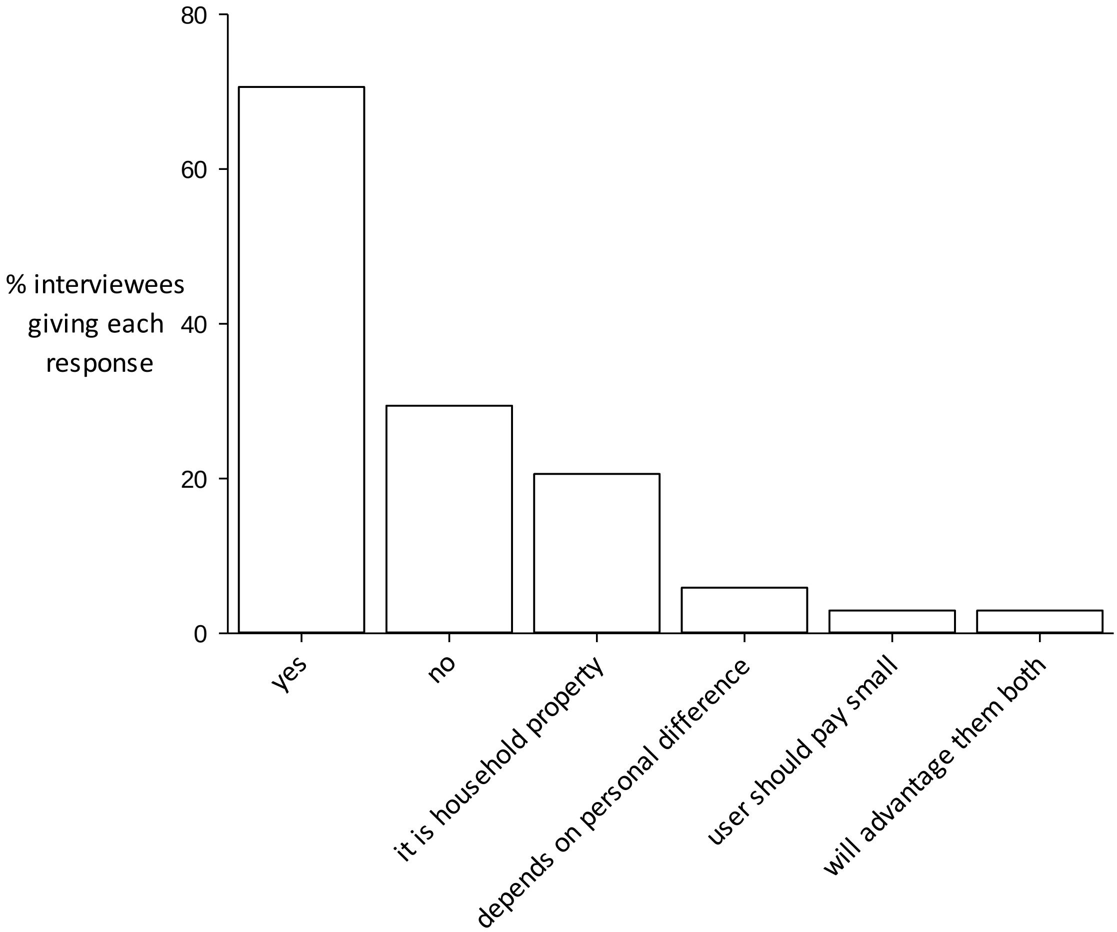

Figure 5.13 Responses to 2011 interview question 'can people use their household member's cattle?'
Note: some respondents gave more than one answer. Each said yes or no, some added comments represented in bars 3-6

So although the use of an individual's capital could imply a type of capitalist market model, when that individual has access to household labour, or is obliged to share their individual physical capital with their peers, the functioning of the Dagomba household as a reproductive unit means that private ownership coexists and overlaps with the traditional system of borrowing and sharing. Individual private ownership of large items of physical capital like *benzirra* thus provides the necessary conditions for such traditional systems to operate. This system prevails in the study communities and its importance will be repeatedly observed.

A further example of such capital accumulation illustrates the scales at which it acts. Patriarchal household heads and senior men make profit by hiring the services of their cattle to their neighbours, notably for ploughing (which includes the service of a junior male to handle the plough), as the capitalist economy functions on the community scale. But once such lumpy items of physical capital are owned by the richer individuals in the community, there is space for the traditional systems of sharing and borrowing to co-exist at household and community scales as kin, household members and neighbours exercise their usufruct rights over these large items of physical capital as well as sharing their human capital, as described in section 5.5.1.

Some authors consider kinship and especially lineage to be the basic unit of 'traditional' society (Cobbah 1987; Holy 1996). In his study of entrepreneurs of FraFra ethnicity, Hart (1975) gives a particularly good example of how kinship is a major locus for begging, borrowing, 'help' and conversion of financial to social capital in Northern Ghana. Yet within the study villages, membership of the same household and community were more commonly mentioned than kinship as traditional routes through which individuals gained access to each other's financial and physical capital.

Capital had rarely been used on a larger scale than that of the community to gain access to a *benzirigu* before the 2010 group donkey experiment. There were limited examples of households borrowing *benzirra* from relatives and friends in neighbouring communities as part of traditional agreements. Yapalsinaa recounted how he had borrowed a bullock cart from his relative in an adjacent village to carry harvest from the farm to the house and returned it full of produce as payment. One farmer from a neighbouring village who hired the Ypilgu group's donkey cart to carry his manure wanted to pay for the hire with manure. These barters may not necessarily attract profit and thus lie between capitalist accumulation and the exchanges of the traditional community. The image of the household unit of reproduction is thereby reinforced, with a more direct hire market acting between rather than within households.

Coexistence of the capitalist and traditional modes can lead them to conflict with as well as facilitate each other by compromising the excludability of goods: the demands of kinship can be so strong that vehicle owners are expected to break hire contracts to lend their *benzirra* to relatives. When the Ypilgu group hired the *trocko* for six days from an adjacent village the owner retrieved it after two because his family wanted to use it – the traditional economy of *his* village was taking precedence over the income he would gain from hiring it to Ypilgu. In his case kinship was a motivation. High demand also increases the subtractability of goods - one person's use of bullocks affects the other's in the sense that they cannot use the vehicle simultaneously, and heavy use further depreciates the utility of the good. Such competition leads market and traditional functions to conflict further. The relative priority of capitalist hiring of cattle and the traditional use of them for household purposes differs between individuals, ultimately depending on non-structural factors like individual family tradition.

This latter point prompts Bloch's (1973) observation that it is not always possible to model the non-structural reasons for the traditional economy. Altruism, morality and obligation are possible motivations for sharing and lending that cannot be considered in game-theory models based on lenders' expectations of reciprocity such as those employed by Thomas and Worrall (2002) and la Ferrara (2003). Such cultural explanations for traditional solutions are common, as in Cobbah's (1987) description of 'obligation' 'cooperation' and 'responsibility' as characteristic of 'African communities'. The responses and actions of bullock cart owners indicate that these motivations do play a role in the persistence of the traditional mode of capital distribution. The owners may also enjoy social capital and status that accrues to them in reciprocation for their benevolence.

A more cynical interpretation is given by Berry (1993) and White (2000). Capitalists may lend to keep others indebted to them. White describes how 'quasi-kin' relationships are used to disguise the obligation to continue commercial relationships: examples of unsolicited favours requiring eventual reciprocity are a part of everyday life in Dagbon. Additionally, Hart (1975) describes how entrepreneurs who are substantially richer than the rest of their community are obliged to 'help' their family and community members in recognition of the help they received on the route to success and to assure further future support – e.g. in standing for political or traditional office. This situation is less applicable to the study communities, where all but one *benzirigu* owner was resident in the village and therefore likely to benefit very directly from any reciprocation borrowers of their vehicle could give them. Within a community the richer and the poorer can all benefit from lending and borrowing (Goldstein *et al.* 2002), and the differences in wealth in these villages are not great when compared to the national scale. Reciprocity and altruism would therefore seem equally reasonable explanations for lending or sharing one's *benzirigu*.

It is important to distinguish between the types of group labour involved in the 'traditional system', the participatory system to be described in the following section and what Marx termed the 'communal' mode of production. The latter is rarely in evidence in the study villages. Group labour is occasionally used for communal benefit in Dagbon, for example when building a new mosque or demonstrating farm practice in MOFA extension workshops, but more usually involves diffuse reciprocity of food and labour in farm work parties. Pooling labour, as families work in household groups to carry their compost to their landlords' farms, is generally for personal or household accumulation within the traditional reproductive system.

Similarly, authors rightly find it difficult and possibly sometimes irrelevant to separate the group actions occurring in the participatory and traditional systems. Chapter two explained that this study distinguishes between formally organised, participatory groups and the spontaneous individual interpersonal social activity that forms the basis of the traditional paradigm. This distinction has proved useful for this work but may not fit every situation as the social capital used in these two types of interaction stems from the same cultural root. Adams *et al*. (1998) give the very common example of formally organised participatory groups based on kinship, an element that can be associated with the traditional system and even forms the basis of the lineage mode of production (Holy 1996). Nigerian hometown organisations are another type of formally organised institution based on ties of obligation, paternalism and benevolence (Barkan *et al.* 1991; Meagher 2010), in their case derived from the community scale. In this study though, the social capital organised at the community scale in the groups using the wheelbarrow and donkey explicitly drew on the participatory paradigm, and that system will be explored next.

5.5.3 Social capital in group work

It was not possible to perform a controlled experiment testing the advantages and disadvantages of group 'participatory' ownership against individual capital ownership under otherwise homogenous conditions. Such an experiment would involve thousands of participants, which is why studies like this are limited to trying to make comparisons under real-life conditions.

Farmers' opinions on the relative merits of the different *benzirra* they used contributed to the analysis. Table 5.3 shows that over 10% mentioned waiting to use the donkey as a disadvantage of its status as a group object. Thus donkey carts are not entirely subtractable – their ownership by a group is problematic as users compete to use them at the optimum time. Such timeliness is in fact the key mechanism through which financial capital works to facilitate effective carriage of compost and thus agricultural success, so it is worth explaining the technical details of its functioning here before it is tackled more specifically and in depth in Chapter 6.

The importance of timely practice for good yields is not limited to fertilisation - its effects range from optimum germination when seeds are planted immediately after rain (Fowler and Rockstrom 2001; Giller *et al.* 2009) to minimal post-harvest loss when harvest is rapidly removed from the field. Where there are such agroecologically determined deadlines, labour bottlenecks are the constraint upon production, which, in the absence of mechanisation, are traditionally overcome with communal labour in work parties.

In terms of fertilisation, synchronisation of nutrient supply and demand is key (Murwira *et al.* 1993; Mafongoya *et al.* 2006; Vanlauwe *et al.* 2010), avoiding both plant stress at times of peak requirement (Ganry *et al.* 2001) and nutrient loss if supply exceeds momentary uptake. Split application of the more mobile nitrogen is therefore advocated, and, crucially in the case of maize, macronutrients, especially P for root development, must be available before flowering (Belfield and Brown 2008). When organic fertilisers are used, pre-sowing incorporation by tillage is a less labour intensive and more effective method than post-emergence spot application, but to avoid erosion, leaching (Nyamangara *et al.* 2003) and volatilisation (Brouwer and Powell 1995; Rufino *et al.* 2006; Gentile *et al.* 2009) amendments should not be applied more than a few weeks before sowing. This means all compost should be carried to the fields between the onset of the rains in April and sowing in June, so all farmers need access to compost carrying *benzirra* at that time. As farmers mentioned that waiting for the donkey was a problem, the participatory mechanism, although it provided some respite in the absence of individual assets, failed to provide quite enough financial and physical capital to fulfil all the farmers' needs for timely soil fertilisation. This was confirmed in 2011 when 44% of respondents stated that one donkey was not enough for the group – it is not entirely subtractable. Farmers dwelt upon this as well as other advantages and disadvantages of group work in more depth in longer interviews, summarised in table 5.5.

Table 5.5 Farmers' perceptions of advantages, disadvantages and necessary skills for group work

Advantages	**How many farmers mentioned this**
Sharing ideas	8
Unity	5
Teamwork	1
Motivation	1
Getting help from other group members	1
Sensitisation to important issues	1
Disadvantages	
Time conflict/waiting to use group-owned physical capital	19
Arguments	5
Group can collapse	2
Jealousy of the leader	2
Individuals spoiling group equipment	2
Not owning up to spoilage	4
Maintenance of equipment	2
If not a member initially may be hard to join later	1
Can collapse if one person says it is useless	1
Necessary skills for group work	
Obey the rules	3
Unity	2
Discussion	2
Attend meetings	2
Patience	1

The inability of the participatory mechanisms to meet fully all farmers' needs for timely fertilisation may reflect the difficulty of locating sufficient social capital. Participants emphasised that the tools for successful group work were regular meetings, communication and discussion between group members. This result was heavily reinforced in the 2011 interviews, when 44% of participants named more regular meetings as a necessary improvement to the functioning of the group. Participant observation confirmed many of the farmers' perceptions: discussion and sharing ideas in meetings were essential to resolving any of the issues the groups encountered e.g. the schedule of use of the cart, payment for hiring outside the group, death of a donkey and jealousy of the facilitator. However, although the farmers' emphasis on peer discussion may seem to emphasise an egalitarian structure, this was not entirely the case. The group could not work as a non-hierarchical body. There had to be a leader to organise use of the group property and collect money, someone responsible for its maintenance and, in the case of the donkey, a driver. Those individuals contributed their time disproportionately to these activities, whilst other participants became jealous of them, putting strain on personal relationships.

More general social 'costs' all members 'paid' for being in the group were the time and effort they spent attending meetings (Oliver 1984; Wandersman *et al.* 1987), the compromises they made in group decisions and the risks they then took of offending their neighbours (Prestby *et al.* 1990). The solution to these problems was summed up by Ypilgu's Kokonaa: 'patience'. These social costs of participation replace the financial capital necessary for an individual to buy a *benzirigu* that would belong to them alone and could possibly be hired or borrowed by friends and relatives as part of the traditional system. Nevertheless, farmers' decisions to participate in the group showed that in 2010 these social costs appeared more manageable for some than the cash required to implement the capitalist/traditional solution of individual ownership.

This prompts consideration of the circumstances under which each of the systems is most appropriate. Prior to 2011, individual ownership had formed part of the solution for some individuals, and the viability of this increased after some individuals obtained *benzirra* of their own. For those individuals who did not have access to the financial capital to purchase or hire *benzirra*, the traditional system of sharing and borrowing had in the past provided an element of access to the physical capital of such richer neighbours. However, this solution means the individual hoping to borrow such capital must have a certain amount of linking social capital. More crucially, it requires an input of one individual's financial capital to facilitate access to physical capital like *benzirra* in the first place (Mpedi 2008). Prior to the appearance of the three bullock carts in Ypilgu in 2011 there was no such *benzirigu* available there and there was only one donkey cart owner in Zaazi, so the possibilities for this type of interaction in the study villages were few.

This is why the group participatory solution may sometimes be the only viable answer: in the absence of one individual's capital, a group formed at the community scale can use social capital to substitute for an individual's cash or at least gain access to an external source of money with which to provide the physical capital that others will then share or borrow. It should also be noted that this group ownership solution is easier for less subtractable items like carts, where the only sense in which users may compete is giving their time. An example of the circumstances under which such community motivation is appropriate can be found in South-Eastern Ghana. Dei (1992) describes an instance of community social capital being harnessed in times of stress. Farmers in Ayirebi and Asokore, Eastern Region, used group strategies like cooperative farms in times of economic shock such as when many migrants simultaneously returned home having been expelled from Nigeria in 1983. State support was not forthcoming at the time, hence participation built on a traditional base may have been the only viable solution.

This is similar to the situation the Northern smallholders encounter - a lack of support from state or individuals prompts them to source capital located in the 'community'. This is a common strategy in similar situations across the continent, to the extent that governments recognise their own failings: Mpedi (2008) describes the South African state's explicit promotion of informal, traditional welfare institutions as a 'complement' to (or a substitute for?) state provision. Gerdes (1975) similarly speculates on how appropriate group participatory solutions rooted in tradition are substitutes for formal state social security in Ethiopia. Bates' (1981) observation that community participation is most valuable in risky situations most resonates with the findings of this study - especially as he identifies the monomodal savanna as one such risky environment.

Differences between the two study villages confirmed this pattern. The donkey group in Zaazi was less successful - i.e. made less use of - than that in Ypilgu. Here, cash vegetable cropping meant that farmers were more able to afford fertiliser and relied less on compost. This was evidenced by the propensity of Zaazi farmers in 2010 and 2011 to carry household refuse ('*tampooli*') rather than compost to their farms and the fact that bowls of fertiliser were available for sale in Zaazi but not in Ypligu. This lack of need for compost could be one reason they were less willing to invest social capital and use the group donkey. Secondly, hire donkeys were available in Zaazi. Better-off farmers conceivably preferred to use them than to expend the social capital necessary to liaise with the facilitator for use of the group donkey. Indeed, one farmer did hire one of these donkeys for his compost carriage in 2010. Another used the group donkey alongside that owned by his father - a case of the traditional system of kinship borrowing. Maybe the social capital requirements of a group are so demanding that they are resorted to only in instances where the private ownership and therefore traditional access to a much needed good like a *benzirigu* is impossible, as was the case in Ypilgu in 2010 or in the case of an entirely subtractable good. This corresponds with the observations of Bates (1981) and Dei (1992) that community capital is likely to be drawn upon in emergency situations when no other capital source is available. As the members were less interested in it, the functioning of the group in Zaazi probably resembled more the 'forced' and 'passive' participation mentioned by Pretty (1995) than the original idealistic egalitarian ideas of Chambers.

As the financial capital owned by individuals in the study villages rose and more private *benzirra* appeared, the environment became less of a 'risky' low capital situation and the viability of the capitalist-traditionalist solution grew. With the increased possibility of hiring and borrowing these *benzirra*, the desirability and necessity of using social capital to form a participatory group reduced.

As well as existing under different levels of capital, these systems operated at varying scales. The individual scale was related to accumulation of financial and physical capital and the household scale to sharing that between peers in the traditional mode. In the study villages the spatially defined village or 'community' was also commonly cited as a group with which respondents felt solidarity. This is summarised by the aforementioned statement of the facilitator in Zaazi in reference to his intended purchase of a donkey cart: that the whole community was 'one family'.

This community scale was particularly appropriate to the participatory mode of organisation. Those in the group in Zaazi even refused to hire a truck or bullock cart from an adjacent village because they felt that at one mile away it was too far. Bates (1990) and Guyer (1981) recognise that, despite the emphasis placed upon them in the 1970s modes of production debate, lineage and kinship are not necessarily the most important structural components of rural life. Vaughan (1985) also describes disagreement over the appropriate unit of analysis for social organisation, citing a case where Malawian women formed grain-pounding groups based on friendship rather than kinship. Berry (1993) reveals a possible reason for the preference of those in the study communities to organise at the scale of the village – ties based on kinship are everlasting and do not necessarily need reinforcement, whereas less ‘moral’ (Bloch 1973) relationships like those between labourers in work parties need constant practice to maintain them. This could be an explanation for the popularity of community-based groups: respondents repeatedly emphasised the importance of having meetings, to ‘remind’ each other of their relationships and obligations towards each other. Goody (2007) also speculates upon the origin of the organisation of Northern Ghanaian villages around a central shrine. Other explanations could entail the organisation of Dagbon as a state with hierarchical group leaders rather than an acephalous, lineage based, system like Konkomba, or even the prevalence of stony inhospitable land around the study communities forcing spatial agglomeration. Nevertheless, despite the importance of the community scale to those in Ypilgu and Zaazi, the concept of group ownership of physical capital on a communal basis within the community was new to farmers despite a history of group formation for other purposes such as labour parties.

So as well as an object’s characteristics, such as its subtractability, the availability of the capitals necessary for its use determines the most appropriate use system in any situation. The most important here is the users’ relative financial wealth and thus ability to satisfy their needs.

The capitals identified as important thus far in the study villages have derived from individuals and their households and occasionally from their communities. The capital of the state is almost entirely absent from the IMT scene. Of course, government has supported the development of mechanised traction with the tractor loan system described in Chapter three, and it may be that the richest farmers in the study villages might be able to obtain a subsidised tractor on credit in the next few years. The local and national government focus on infrastructure at the district level further promotes motorised transport. These interventions widen farmers’ options, primarily through better market access. However, the disjuncture between them and the scale at which the participant farmers operate illustrate that, as yet, the two do not fully intersect. As well as trying to get produce to the markets along paved roads, farmers are still tackling the less visible problem of getting inputs to their farms. The most obvious way in which the state could contribute to intermediate transport solutions at the village and farm scale would be through supporting individuals, and maybe groups, to gain access to *benzirra* through subsidising imports, reducing import taxes or even facilitating relationships between them and donors. None of these solutions is in evidence in the study region, leaving a situation in which capitalist and traditionalist systems dominate and there is a smaller space where the participatory system has potential to emerge.

However, as Chapters two and three constantly reiterated, such strict categorisations, divisions and distinctions between systems are dangerous as most actions exist at the boundaries between coexistent typologies: a variety of sources and types of capital may be required for access to one *benzirigu*. It is therefore less relevant to try to assign any one situation to a particular paradigm, particularly considering the interscalar nature of the 'traditional economy' and the links of kinship and reciprocity that often mix with market exchanges in this setting. Contrary to the representation of Cobbah (1987), who pits an idea of Western capitalism against African communitarianism, they are not mutually exclusive.

So a variety of capitals and substitution between them facilitates best utilisation of each mode: a better, more expensive bicycle requires less human capital to ride, larger headpans or sacks require fewer people and larger *benzirra* mean fewer trips. If a farmer uses their own bullocks, they or their father must have had a large amount of financial capital at some point with which to purchase this physical capital. Alternatively, if they borrow cattle they must have a certain amount of social capital. If they decide to hire a truck, a large amount of human capital is also essential. Social capital is also necessary to coerce household members to help and financial capital helps maintain bicycles and headpans. It is, however, more important for a farmer to use those multiple capitals to give him access to a range of *benzirra* than to concentrate on use of one alone, something to be elaborated on when considering the synergistic effects of a mixed mode work party to be demonstrated in section 5.8. Most importantly, all these forms of interchangeable capital must be available in time to get the compost onto the field two to three weeks before sowing.

The importance of timely practice as the mechanism through which financial capital acts to facilitate effective SFM has been explained. Combining multiple capital use systems allows farmers access to more resources and thereby a wider range of SFM and transport strategies, some of which will hopefully be available at the right time. To some extent the use of substantial human capital in the form of one's or one's household member's own bicycles and headpans, unpopular though it is, can help facilitate timely SFM because it adds to or substitutes for high capacity animal-drawn *benzirra* to give farmers further options for getting amendments to the fields on time. The importance of timeliness is especially well illustrated when considering which was actually the 'best' of those high-capacity animal-drawn *benzirra.*

5.6 Bullocks vs. donkeys

It has already been seen that animal-drawn *benzirra* are the most efficient (figure 5.1-6) and preferred (figure 5.7). The data in tables 5.2 and 5.3 also illustrate some specific, crucial points gleaned from interviews and participant observation regarding the relative usefulness of bullock and donkey carts. When combined with the farmers' expressions summarised in table 5.6 these shed further light on the mechanisms through which donkeys eventually outcompeted bullocks.

Table 5.6 Comparing bullock and donkey carts.

Bullocks	**Donkeys**
Work related	
Larger capacity cart	Smaller capacity cart
Traditionally used to plough	Not commonly used to plough
Only work mornings	*Work all day*
Two animals required	*One animal required*
Can only hire cart so need own bullocks	*Donkey hired with cart so anyone can hire*
Using them to carry compost loses ploughing earnings	*No loss of earnings*
More expensive	*Cheaper*
Other	
Meat	
Milk	
Hide	
Rich manure for composting, plastering and fire	
Ceremonial function	

Note: *More advantageous in italics*

The benefits of the donkey over the bullocks explain why figure 5.14 shows that fewer people actually used the bullock cart than the donkey, despite figures 5.1-6 that showed that the bullocks carried the highest volume of compost per person-hour and figure 5.7 where farmers ranked bullocks higher than donkeys.

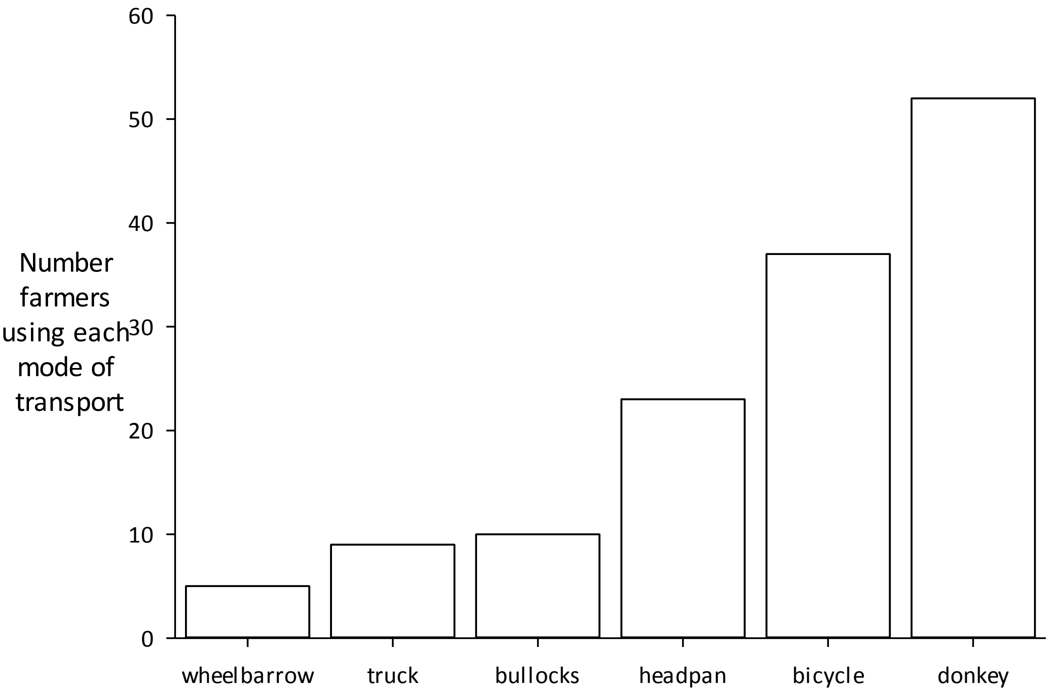

Figure 5.14 Farmers' use of each *benzirigu*.

The problem most often mentioned in relation to bullocks in table 5.3 is that not all farmers owned them or the cart. This is not a technical problem: table 5.6 shows that many farmers lack the financial capital with which to buy them. In interviews in 2011 farmers explained that cattle were indeed more valuable because they could plough as well as carrying loads. The multiple uses described in Chapter 3 - milk, manure, hide and meat - meant they could perform ceremonial roles in funerals, weddings, outdoorings and chiefly enskinments (enthronements) (Starkey 1990), which is why they were two to four times as expensive as a donkey: 300 - 800 GhC compared to 200. Although two bullocks were normally hitched to a cart and could therefore carry a larger volume than a donkey, their greater cost due to their higher functionality and thus traditional role meant the donkey was cheaper per unit volume when it came to carriage, and was therefore pigeonholed in this role. Had there been a pair of bullocks available to use free of charge with no loss of earnings it is certain most farmers would have used them as they did the donkey: when asked in 2011 whether a bullock group could exist in the same way as the donkey group, 100% of farmers asked in Ypilgu and 97% in Zaazi said yes. A comment from another bullock owner illustrates this point further: Mr Yahaya, Yapalsinayilli, Ypilgu said that he himself preferred the bullocks because of the larger volume cart they could pull, but for the majority who did not own bullocks, the cheaper donkey cart was better. Confirming this, as for most individuals, the bullocks were too expensive for the group to purchase, hence participatory ownership was limited to donkeys.

Two other factors illustrated in table 5.6 made bullocks less appropriate for compost carriage. The second commonest problem was the fact that bullocks have a specific time for work; as ruminants, they need to graze for longer on higher quality grass and have less stamina than donkeys. They can work from dawn (around 6 am) but must be released to go to graze in the bush around 9 am, whereas, depending on how hot the day is, a donkey may work until midday and return to work between 4pm and dusk. This issue was identified in the first round of in-depth interviews and confirmed in the field and in the 2011 interviews. It is why, as noted in table 5.2, many mentioned the ability of the donkeys to work all day as an advantage. This slightly lower subtractability means the donkey is therefore also more appropriate for a group situation when many people need to use it at the same time during peak farming season - one farmer's use of it in the morning does not preclude another's in the afternoon.

A third important problem with bullock traction is that the optimum time for carriage of compost is the beginning of the farming season, just when bullocks are needed to pull the ploughs. Although only 10% of bullock users mentioned this problem when asked to list the disadvantages of the bullocks, its importance became apparent as the season progressed. After the first round of compost carriage farmers waited until they had accumulated sufficient manure to begin a second round. When a meeting was held in May 2010 to arrange *benzirigu* hiring for the second round, the farmers who had previously used the bullocks and the handcart opted to switch to the donkey because of the conflict with ploughing. In the case of the handcart this was because human capital was limited at this time of year as young men were busy weeding the groundnut farms and felt too tired to pull the handcart as well, resonating with the description of African agriculture as labour rather than land limited (Swindell 1985).

However in the case of the bullocks the pressures of financial capital were also at play: bullock owners were hiring out their cattle to plough others' fields and did not want to forego that income when a free *benzirigu* in the form of the donkey was available for compost carriage. Thus as the capitalist mode of hiring draft introduced with bullock traction 30 years ago articulates with traditional household reproductive functions there is also a capital implication for farmers. It is interesting to note that even the participatory solution of a group-owned *benzirigu*, ostensibly helping the poorest non-*benzirigu*-owners, actually preferentially benefits those who already have the financial capital to buy cattle and therefore control the bullock hire market. Many have commented on the continued injustices of participatory solutions (Cooke and Kothari 2001) and their propensity to perpetuate existing inequalities, just as ownership of the means of production may accentuate differentiation.

Therefore, although cattle have more traditional roles and are more generally useful to a holistic Dagomba livelihood, when carriage alone is considered the donkey is more suitable precisely because of its limited functionality and therefore lower cost. This comparison of the bullocks and donkeys illustrates the importance of financial capital and the mechanism of time through which it acts. Farmers prefer whichever vehicle they can gain timely access to at a cheaper price. Ultimately, the ability to choose between a mixture of resources - the more expensive, stronger cattle with a larger cart and the cheaper donkey with greater stamina - would be best.

The technical superiority of the donkey is thus entangled in the more complex issues of financial capital, hire markets, access and ownership. This is connected to the question of whether an individual's financial capital can be entirely replaced by the social capital of a group, which will be explicitly dealt with in the final section of this chapter.

5.7 Individuals' capital and amount of compost carried

Having established that larger, more expensive *benzirra* facilitate efficient carriage of more compost it was instructive to examine individuals' capital endowments to confirm whether there was a relationship between their assets and their ability to transport compost.

Seven parameters measured by the census were chosen to compare to the volume of compost each farmer carried and the efficiency of their carriage. These parameters, described in Chapter four, were chosen because they reflected a farmer's capital endowments and what their interview responses indicated were the key factors affecting their ability to carry compost. The first two measures, - the number of people in each house and the index of access to labour - reflect human capital endowments. The next three - an index of a farmer's access to bicycles, both their own and those of their farm helpers, whether there is a *benzirigu* in their household and whether there are bullocks in their household - specifically measure their access to forms of physical capital used as means of transport. Bullock ownership, like the sixth parameter, livestock ownership, reflects a farmer's access to manure and acts as a general proxy for financial capital (Croppenstedt and Demeke 1996; Dercon 1998; Morris *et al.* 1999; Rowe *et al.* 2006; Dossa *et al.* 2011). Finally, so does whether they have any income other income than farming. These seven parameters were each divided into two or three categories and non-parametric tests were carried out for differences in the mean total volume of compost carried by each participant and the volume of compost they carried per person-hour*kilometre between those categories. For scale parameters, correlations were also carried out between the non-categorised independent variable and both total volume of compost carried and volume of compost carried per person-hour*kilometre. There were clear relationships between the total amount of compost carried and access to labour, bicycles, *benzirra* and livestock. Household size and cattle ownership also had effects. Significant results are indicated in ***bold italic text*** in the following tables.

Kruskall-Wallis tests showed no significant difference between the three categories of household population in terms of amount or efficiency of compost carriage.

Table 5.7 Effect of number of people in house upon compost carriage.

		Total volume carried (m^3)	Volume per person-hour*km (m^3km/ph)
Means within categories	1-14 people	2.4062	0.1820
	15-28 people	4.4882	0.1598
	29+ people	3.9982	0.1367

There was, however, a significant correlation between the scale variable of household population and the amount of compost carried ($R=0.63$, $p< 0.05$).

This correlation is not surprising. Sheer quantity of human capital meant larger houses could use more people to carry compost. However these people were not necessarily the most able – in fact those carrying the landlord's compost were often children who used small *tahali* so their time efficiency was low. Therefore an index of access to labour was constructed, as described in Chapter four, which considered helpers' age, gender and current school attendance. When the scale variable was divided into three categories, a Kruskall-Wallis test showed that there was a significant difference in the total volume of compost carried by households in each group ($H=6.391$, $p<0.05$).

Table 5.8 Effect of access to labour upon compost carriage.

		Total volume carried (m^3)	Volume per person-hour*km (m^3km/ph)
Means	Index rating of 0-8	***2.2876***	0.1794
	Index rating of 8-15	***3.7616***	0.1431
	Index rating of 15+	***5.7380***	0.1638

Correlation showed that those with more access to labour were significantly more likely to carry more compost ($R=0.366$, $p<0.01$), but still did not carry more compost per person-hour* kilometre. Those with more labour can therefore put in more person-hours using any mode but in 2010 were not particularly more likely to use a high capacity *benzirigu.*

Illustrating this, the Ypilgu chief's son commented that as he had children with bikes and wives with *tahali*, hiring the *trocko* for a second round was unnecessary. A relevant point here is that for this task, an individual's access to child and male labour within his household is important (Berry 1989). Women do sometimes carry compost in *tahali*, but overall responsibility for transporting it to the maize farm falls to men due to their socially recognized duty to provide the cereal crop that feeds the household. It is easier for a man to demand children to help him with this task than women, who have their own distinct reproductive tasks to perform – for example fetching firewood and water, washing and cooking. When asked whether their house women helped men to carry compost to the farm a frequent response was 'if they have time'. Men are more likely to ride bicycles in Dagbon (Porter 2011). They also push the *trocko* and drive the bullocks, something adult women were never observed doing. Children's work is important (Andvig 1998) and a specific task allocated to boys here was to work with the donkey: boys were appointed in both villages as official donkey drivers, although adult supervision and assistance was necessary for braking and pushing.

Figure 5.15 Young donkey drivers in Ypilgu.

These drivers pointed out that 'children do composting more than adults' ('*bihi niŋ kulum tam gari ninkura'*). As well as carrying their parents' compost to the maize fields young people use it for their own cash tomato and pepper farms. Children make a very important contribution to high and low capacity modes of compost carriage. The establishment of a school in Ypilgu in 2009 and the fact that children under seven are now more likely to go to school than they previously were has implications therefore for the carriage of compost.

Bicycle ownership was also strongly related to the total amount of compost carried. The correlation between this variable and the index of access to bicycles was highly significant ($R=0.296$, $p<0.01$) as was the Kruskall-Wallis test for volumes of compost carried by households belonging to each category of this variable ($H=13.564$, $p<0.01$).

Table 5.9 Effect of access to bicycles upon compost carriage.

		Total volume carried (m^3)	Volume per person-hour*km (m^3km/ph)
Means	No bicycle themselves but a helper has one	***1.199***	0.1604
	Has own bicycle	***2.135***	0.1809
	They and 3 helpers have bicycles	***4.377***	0.1571

Those with more helpers could ask those people to use their cycles to transport compost to the field. Also, as bicycles are generally owned by men and compost carriage to maize farms is a male task, the more bicycles in a household the more men, who were also expected to help use higher capacity *benzirra*. The effect of access to such *benzirra* is displayed in table 5.10.

Table 5.10 Effect of access to *benzirra* upon compost carriage.

		Total volume carried (m^3)	Volume per person-hour*km (m^3km/ph)
Means	No *benzirra* in house	***3.2355***	0.1630
	Benzirigu in house	***7.5024***	0.1894

The significant difference in amount of compost carried between those who had a *benzirigu* in the house and those who did not (Mann-Whitney U=48.0, $p<0.05$) shows that this did normally translate into access to that particular *benzirigu*. Indeed, the case study of Yahaya of Yapalsinayilli in Ypilgu who was given a donkey by Heifer International in 2010 illustrates this. His brother Abukari said in interview that 'the whole house' was able to use Yahaya's donkey. No arguments arose over sharing it, although its slightly subtractable nature meant it was difficult to find time for it to work on everyone's farms. These observations confirm the importance of the traditional mode of household production and labour sharing between kin in providing many people with access to the financial capital of an individual.

Yahaya's case study provides an opportunity to diverge and illustrate the fluidity of more than just individual and household physical and human capital. Yapalsinaa, Abukari and Yahaya's father, is the landlord of the most populous and possibly the wealthiest household in Ypilgu, the only dwelling in the village to be entirely roofed in zinc. He has four wives and a motorbike. His third oldest son, trained as a mason, owns a wheelbarrow. Yapalsinayilli does not own more land than others in the village - about 15 acres - but was employing a strategy of borrowing and hiring land outside the village for cultivation. Yahaya, Yapalsinaas second son, speaks English, and due to this human capital he chairs the group started by OIC, the NGO that donated ruminants and introduced composting to the village. Ypilgu's OIC group is viewed as particularly successful, hence local OIC staff brought guests from Accra and America to see the village in 2010. This mixture of the villages' and his own social capital has given Yahaya access to more human and financial capital as he has been trained by OIC and the local veterinary volunteer as a community livestock worker and he can inject and treat OIC and personal animals, charging cash for the latter. Yahaya has also concentrated on developing his livestock herd and now owns around 30 goats and sheep. Because of his success in raising his own physical capital, Ypilgu's OIC representative recommended Yahaya to Heifer International, OICs parent body, as someone who would be able to participate in their trial of the donkey cart in Northern region and they gave him one on credit in 2010. Thus, through him, Yahaya's household has gained access to that NGO's external physical and financial capital. To some extent it is also available to the community through the hire market - something that will be explored in section 5.9. Ramisch (2004), Moseley *et al.* (2010) and Gray (2005) describe how larger households do tend to be richer, an opinion expressed by interviewees in Dagbon. They can therefore compete well in capitalist as well as traditional economies. The mechanisms through which this works are disputed; simultaneous processes of production to feed more labour and higher labour availability for surplus production probably interact with high labour:dependent ratios when children are not at school (Rakodi 2002). Whatever the mechanisms, Yapalsinayilli's story is a good illustration of the exchange of financial, physical, social, and human capital at the household scale as well as between this and the individual, community and NGO.

The only player not mentioned in this case study is the state, and this observation provides an opportunity to confirm the limited applicability of structural solutions to village transport problems. The capital of central or even regional or local government has not yet flowed 'down' to this level. Both research observation and anecdotes corroborate this. When OIC visited the village in 2010 they asked for questions and suggestions from villagers. The village teacher raised three points: the lack of a school feeding programme, the need for donkey carts to carry compost to the fields and the state of the road leading to the closest town, Kumbungu. This unpaved road is rutted and sandy, partly due to the passage of trucks collecting sand for sale to construction companies. When the local assemblyman contacted the district executive about this problem the resolution was that the issue of sand trucks traversing the road would not be tackled by local government but the road would eventually be paved. Ypilgu's Assemblyman, Alhaji Issah, confirmed in 2010 that an assessment survey of the site had begun, so it may be anticipated that work could commence in the next few years. If the most local level of government is still at the first stages of tackling intervillage roads it is evident that state capital for transport purposes cannot stretch to the intravillage level. This may be symptomatic of the underinvestment in the North mentioned in Chapter three which has pertained since colonial times (Plange 1979; Cleveland 1991; Stevens and Leggerman 2004). Access to an individual or their household's capital, possibly ultimately derived from other external sources like Yahaya's donkey, currently remains a more achievable option. Throughout 2010 and 2011 individuals were observed carrying out road improvements in the study area. Individual farmers removed large stones from farm paths and made makeshift ramps and speed bumps and children filled in potholes on village roads, accepting tips from travellers. A local improvement to the road from Ypilgu to Kumbungu can be seen in figure 5.16.

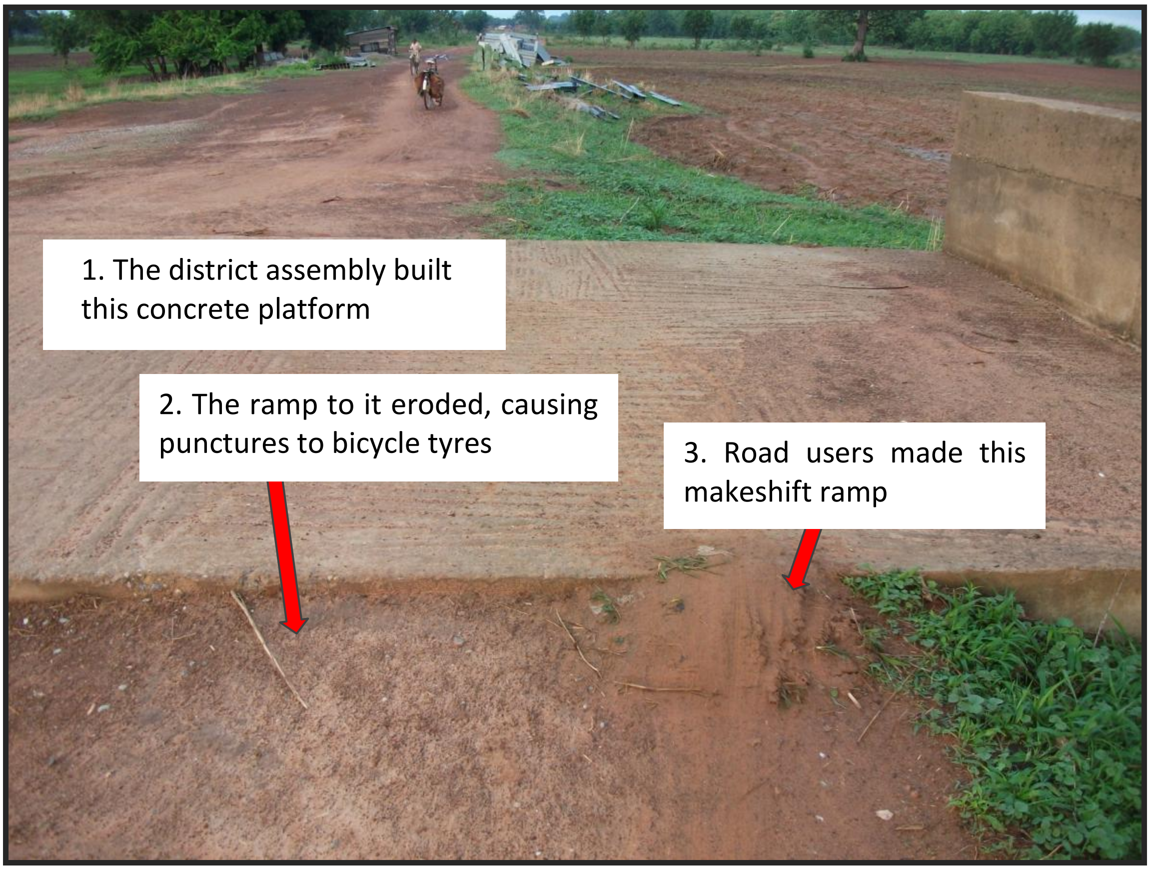

Figure 5.16 An improvement made to the road leading from Ypilgu to Kumbungu.

Community capital was also harnessed - in the rainy season of 2010 an iron bridge across a deep stream that dissected the Ypilgu-Kumbungu road was in a state of disrepair, leading to an accident in which a handtruck fell off the bridge. A 'committee' from the head village of the traditional area Zugu, into which Ypilgu falls, with the authority of the chief, undertook to collect 300 GhC in contributions from landlords in each of the six villages in the area and from travellers across the bridge to pay a welder to fix it. Without this effort the major path to the Kumbungu market would have been impassable. Meanwhile, for the past three years building materials have been placed at the site awaiting the local government to construct a more permanent bridge, but the delay means much has been stolen. Household, community and individual capital are therefore observed to be more expedient than the state in solving small scale transport problems. This is more evidence for the efficiency of traditional and participatory solutions, as implicated by the cost-sharing approach advocated by World Bank authors like Malmberg Calvo (1998) over the solely state-funded approach.

Returning to the effect of individual's capital on amount of compost carried, those who lived in a household where cattle were owned carried more compost to the field, but this difference was not significant.

Table 5.11 Effect of access to bullocks upon compost carriage.

		Total volume carried (m^3)	Volume per person-hour*km (m^3km/ph)
Means	No bullocks in the house	2.2017	0.1771
	Bullocks in the house	4.1941	0.1577

This may be because farmers who were not landlords used some of their household's cattle manure but were not always using bullocks to pull cartfuls of manure to the farm.

The issue of access to household bullocks requires careful analysis. Bullocks in the house may belong to the landlord or his junior male relatives. However, having bullocks in the house did not always mean everyone used them: landlords' sons like Idi in Slimbogngnayilli and Adamkpem in Botongnayilli did not use their fathers' bullocks to take compost to their own farms. There are three possible reasons for this. Firstly, not all bullocks were trained to use the cart. Secondly, it could be that some landlords consider their bullocks personal property, not to be shared with other household members, due to their traditional and economic value (Homewood 2008) and multiple uses. However this sits uneasily with figure 5.13 which shows the responses to the 2011 interview question asking whether it was possible for famers to borrow their household members' cattle. Farmers confirmed that landlords commonly entrust the care of cattle to their junior male kin. In return, those younger men are usually compensated with use rights to the animals' draught power. Although cattle do belong to individuals, their use by different members of the household is an expression of the same traditional system of household reproduction in use in Yapalsinayilli when Yahaya's brothers shared his donkey. Note again that the nature of this good is what defines that way it can be used: only goods that are not entirely subtractable can be shared or hired, although non-subtractable goods can form part of the traditional economy if they are lent in expectation of reciprocity or given as a gift. The example of cattle usufruct again illustrates how personal physical capital accumulation facilitates a traditional system of sharing and borrowing at the household scale.

It is thus most likely that bullocks in the house did not significantly affect amount of compost carried per person-hour for a third possible reason - individual differences in household dynamics. Household decisions as to whether an individual can use bullocks are based upon individual's social capital within their household and their relationship with the cattle owners (Vaughan 1985; Goldstein *et al.* 2002).

Qualitative participant observation data led to the conclusion that bullocks, a form of physical capital, in a house eventually facilitate more compost use and faster carriage for the owner, if not always their household members. Due to the traditional household scale of reproduction, this could translate into benefits for all members: if the bullock owner is a senior member of the household and if he produces more maize it is likely to benefit the household as a whole at some point as he is likely to be expected to supplement the landlord's maize if it runs out.

Cattle are a form of livestock, and when small ruminants and poultry are included in an index of livestock ownership a Kruskall-Wallis test confirmed that those with more livestock were able to carry significantly more compost to the farm ($H=7.634$, $p<0.05$).

Table 5.12 Effect of livestock ownership upon compost carriage.

		Total volume carried (m^3)	Volume per person-hour*km (m^3km/ph)
Means	Less than 10 fowl	***1.769***	0.1300
	10 fowl or 1 small ruminant	***2.5152***	0.1438
	7 small ruminants or 1 cattle	***4.2495***	0.1831

As access to bullocks did not necessarily mean faster carriage of compost for non-owners, more livestock probably led to more compost carriage, not necessarily because those livestock included bullocks to pull a cart, but because the farmer was able to produce more manure. As described in Chapter three, in Dagbon manure is generally owned by individuals, not households. Many Dagomba farmers now enclose livestock at night, especially those that are following OIC training, and this makes manure collection easier than if they were entirely free range. When the entire household's animals are kept together at night, the manure from the cattle kraal is most likely to go to the landlord's fields first. Landlords' sons may use manure from their own small ruminants on their individual farms. Access to manure thus depends largely on an individual having their own physical capital in the form of livestock: this loosely agrees with McClintock and Diop's (2005) description of the manure piles owned by Senegalese household heads and the compost piles managed and more commonly owned by women. Participant observation revealed that certain individuals had accessed physical capital held by external agencies: in a scheme similar to that instituted by OIC in Ypilgu, the district assembly gave small ruminants to farmers in Zaazi under the understanding that the capital would be returned and the offspring kept. As farmers had to form a group to join the OIC scheme it could be considered that in this case community bonding social capital was harnessed as an access mechanism to the external physical capital that made livestock ownership possible.

Animals are also a proxy for money (Dercon 1998; Grace 2004; Kristjanson *et al.* 2005). Those individuals who had more animals may therefore also have had more money for other tasks like maintenance of their bicycles, as may those who had other incomes. Admittedly, access to other income does not always indicate great wealth, but in the absence of income data it is one of a range of proxies. More income could lead to more financial capital which might be used to hire or buy larger *benzirra*. However, table 5.13 shows there was no relationship between other income and compost carriage.

Table 5.13 The effect of other income upon compost carriage.

		Total volume carried (m^3)	Volume per person-hour*km (m^3km/ph)
Means	No job outside farming	4.1948	0.1676
	Vegetable farming	1.9746	0.1702
	Anything else	2.5611	0.1321

The explanation that more animals provide more manure is therefore more likely, and it may also be that in some cases financial capital was spent on inorganic fertiliser whilst human capital was expended on carriage of compost using the more accessible low capacity forms of transport.

It has been shown that those farmers with more access to labour, *benzirra* and livestock carried significantly more compost - but not more compost per person-hour. People with more access to their own or their household's capital are thus not more efficient at carrying compost than poorer people. This seems surprising considering that richer people are conceivably more able to use the larger *benzirra* that were shown in section 5.2 to carry more compost per person-hour; it could also seem to conflict with the findings of section 5.4 showing farmers perceive more capital to be necessary for the use of high capacity *benzirra*. Methodological explanations for this apparent contradiction are the disjunctures between what farmers know and what they tell researchers and between people's perceptions and observed reality.

However, numbers must be combined with qualitative data to reveal the whole story: a better explanation is that the importance of cheap head carriage and expensive *benzirra* are not necessarily contradictory. Although more financial capital is *necessary* to use the high capacity *benzirra*, those with the capital did not always use it for that purpose: there is not always a causative relationship. Some richer, larger households did use the bullock cart and, as was shown by figure 5.1 and 5.2, due to its large capacity it did carry significantly more compost per person-hour. But they also put in more person-hours of labour to carry high volumes of compost using *tahali*. This maximised the amount of compost carried but reduced the average volume carried per person-hour.

It is true that many measures of wealth correlate. The association noted earlier of larger households with more resources such as bullocks and *benzirra* may mean that a non-causative correlation is seen between those resources and compost carriage whereas more hours of head carriage is really responsible for the difference. Indeed, those with more access to labour are significantly more likely to have cows in the house (X^2=13.305, p<0.01), access to bikes (X^2 = 37.355, p<0.01) and a *benzirigu* in the house (X^2=7.886, p<0.05). It could be perceived that these correlations between wealth indicators increase the possibility of spurious correlations between them and compost carriage. Statistically this is true, but if all are indicators of wealth the more relevant conclusion to draw is that wealthier families carry more compost due to a range of interacting characteristics of which the availability of labour for headloading is dominant. This reemphasises the interaction of smallholders' different capitals and activities and thus the importance of doing experiments in the real social surroundings to which the results are relevant.

So although some famers used carts and due to this and their higher human capital were able to carry more compost overall, in 2010 no household either had or was using the large *benzirra* sufficiently to carry a significantly larger amount of compost per person-hour. Bullock owners often chose to use their limited numbers of animals for the more immediately economically profitable ploughing instead of using them to pull a hired truck full of compost. Human capital was still contributing most towards the overall amount of compost most farmers carry because there was not yet enough money in the community to support purchase of enough *benzirra*.

Corroborating this, the correlations above show that of all the variables examined, the index of access to labour has the strongest and most significant correlation with total amount of compost carried.

All the proxies for access to capital here were drawn from the suggestions farmers made in their first interviews and are measured at the household or individual level. Although it may have acted as an access mechanism, none of these parameters *directly* reflects capital held at the community level, so these indicate the relative importance of the traditional and capitalist systems but cannot compare this to the relevance of the participatory solution. Nevertheless, participant observation made it clear that although groups do help each other to convey compost, this depends more on an individual farm owner's social capital within the existing traditional communal labour system than any form of formal group organised 'participation'. The person who accrues benefit is the farm owner and compost carrying is rarely a directly reciprocal task. It has been noted that the state does not contribute any capital to solving intravillage transport problems in Dagbon and there is little scope for other structural solutions. An individual's index score of access to labour was a reflection of their own position within the household and not of the total household population, as is livestock ownership and access to bicycles. Even if physical capital is owned within the household, it is an individual's own social capital that allows them access to it or not – as has been seen, despite statements that cattle are available to all household members, young men who did not own their own bullocks did not *always* have access to their father's for compost carriage. This was possibly because of time conflicts between their ploughing needs and those of paying hirers, so their social capital within the household would influence the weight of their case. Therefore, at the village scale, those with substantial individual capital are best placed to use it to carry compost; capital held at the household or indeed the community level can only be accessed by those with sufficient social capital. Individual capital thus currently still has a strong influence on a farmer's ability to access *benzirra,* within a system where its dearth forces them also to engage in participatory and traditional modes of access.

White (2000) and Berry (1993) have also observed overlaps of capitalist and traditional systems. However in their cases social relationships similar to friendship and kinship were used to encourage waged workers to continue to supply their labour. Although this is the reverse situation to that in the study villages, where friends and neighbours exploited a cart owner's personal financial capital, it confirms the co-existence of and synergy between traditional and 'capitalist' systems of capital exchange. Participant observation was the method that revealed these interactions, just as it revealed the synergy between the different modes of transport themselves that will be described next.

5.8 Mixed methods – synergy of modes

Quantitative data tools are designed with preconceived questions in mind. As participant observation brings new themes to light, data collection methods are amended to address these themes. Quantitative data therefore does not always deal as thoroughly with such new subject matter as does participant observation. Sections 5.6 and 5.7 have indicated how the latter was extremely useful in helping infer and explore ideas that had not been anticipated and so could not have been elucidated by the quantitative data alone, such as the links between the capitalist and traditional modes of capital use. Another such theme was combined use of different modes of transport and synergy between them.

Most farmers in Ypilgu and a few in Zaazi supplemented the use of the donkey cart with their own *benzirra* – bicycles or headpans. Of course using multiple modes of transport, whether owned by an individual or group, helped carry more compost as it makes use of all available labour. Several people also used headpans and bicycles simultaneously and it could be conjectured that this is due to the traditional household and gender roles associated with each form of transport, most obviously the role of women and children in head carriage and men in riding bicycles (Bryceson and Howe 1993).

In the second round of interviews farmers made the benefits of such a strategy clear. One of the main reasons for adding one's own *benzirigu* to the group one was that waiting for the group one wasted carrying time – the small extent to which the donkey was subtractable made it necessary for individuals to find alternative solutions. Many, like Fuseini in Zaazi, also mentioned the convenience of carrying compost themselves without having to arrange for the use of the donkey cart, using the phrase 'you don't have to ask anyone, you just wake up and take your bicycle/ headpan' . Table 5.14 confirms that the main reason for use of these low capacity *benzirra* in addition to the high capacity animal-drawn vehicles was the unavailability of the latter.

Table 5.14 Answers to the question 'why did you use your own *benzirigu* as well as the group one?'

Answer category	**Percentage of farmers stating this**
If the group vehicle wasn't available had to use own/ Many people were using the donkey	43.3
Using additional *benzirra* is faster	6.7
Wasn't initially part of group	5.0
To maximise use of available household labour	1.7
To try as hard as possible	1.7

Synergistic as well as additive effects between multiple modes of transport were both described and observed. Those loading the donkey or bullock cart or handtruck would tend to send the loaded cart ahead, driven by children, then load sacks of compost onto bicycles and ride them, overtaking the cart. Having emptied their sacks they helped unload the cart when it arrived in the farm. One person's labour is thereby used more productively than if they were riding a bicycle or loading the cart alone. Teamwork is also often more productive in the farm because of the psychological impetus it lends; household teams of headpan and bicycle users often assist each other, especially with lifting the sack and pans on and off the head and bicycle. Availability of multiple headpans may have been one reason they were more commonly used than the sole wheelbarrow. A linked strategy was the carriage of compost on a bicycle to the farm when the main purpose of the journey was to go to work there, for example to clear or ridge. This multifunctionality of the bicycle, as a form of transport and also carriage, was often mentioned in the second interviews as one of its benefits (see table 5.2). The mixed mode transport strategy made it difficult to collect much of the quantitative data, for example total time each person spent using each *benzirigu*, but added significantly to the value of the qualitative data. This revealed that multiple modes of transport are actually more necessary to successful compost carriage than unimpeded access to one high capacity mode, and reemphasised the importance of timely access to *benzirra.*

5.9 Group and private ownership and its implications for financial and social capital substitutability

This penultimate section of Chapter five will clarify the circumstances under which each of the two dominant systems, capitalist-traditional and participatory, are most feasible and what position the study villages are at in relation to each system. It is difficult to compare empirically how attractive group ownership and hiring were or to measure whether group social capital could fully replace the individual financial capital required to own or hire a donkey cart. When the opinions of the farmers who had ever hired a *benzirigu* were sought on the matter, all said they would prefer to use a group object than to hire one. However sections 5.5.2 and 5.6 gave evidence to indicate that hire markets are possible and also desirable for those hiring vehicles as well as those loaning them.

The 2010 and 2011 acquisitions of bullock carts and donkeys indicate that levels of financial capital were increasing in the study villages (Vehnamaki 1999). Farmers may have decided either to spend new-found wealth on these *benzirra* or to divert existing funds to these tools. In either case, this is evidence that the wealthy at least felt *benzirigu* ownership was cost effective for personal use or hire. In 2010 many farmers outside the research groups came to hire the group donkeys for carriage of compost and hired privately owned bullock carts with their own money. They also paid for use of the donkey donated to Yahaya by Heifer International. In 2011 the researcher suggested charging a nominal fee of 1Ghc to all users in Ypilgu for one day's compost carriage. This was a result of a suggestion from the local MOFA officer, who had observed that carriage to the farm involved more depreciation of the cart than carriage to the market did. Farmers accepted this suggestion with no complaint. Farmers in both Ypilgu and Zaazi also decided to charge for carriage of items including water, mud and sacks of market vegetables and farmers were eager to use these services, although many defaulted to some extent on payment. In Zaazi in 2010 four donkeys belonging to two individuals were already available for private hire and one individual in the Zaazi group hired one of these for compost carriage when the group donkey was unavailable in 2010. These data indicate that it is not merely the fact that group ownership provided free access that made both bullocks and donkeys attractive to those within the group experiment. Their services were valuable enough to warrant payment for all types of functions. A private hire market is therefore viable. The World Bank authors (Riverson and Carapetis 1991; Malmberg-Calvo 1998; Starkey *et al.* 2002) would agree with this - they consider investment of individual capital the best route for providing access to transport. The data here seem to indicate this model is effective, if only the cash exists. Hire markets can be less accessible to the poor and disproportionately benefit the rich (Wanjiku *et al.* 2007). However figure 5.17 shows most farmers in the study villages were prepared to take that risk and pay between 1 and 1.5 GhC (about £0.70p) for one trip.

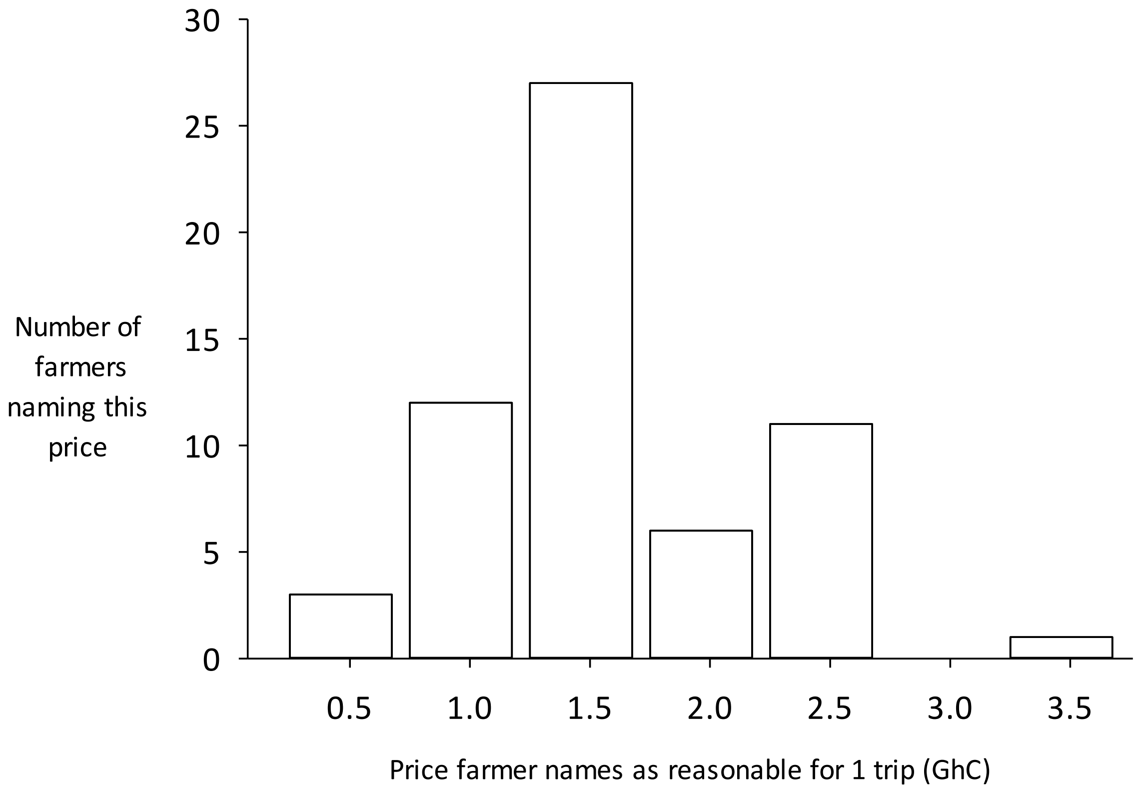

Figure 5.17 Farmers' willingness to pay to hire the donkey cart.

Thus, despite the higher financial capital cost, a hire market does form part of the solution to the carriage of compost to subsistence maize fields, as of other more productive goods like the sacks of parboiled rice women try to carry to the weekly markets to sell. By 2011 it was becoming part of village functioning even without external assistance. This participant observation data on the use of individuals' physical capital reveals most about the interrelationship between different systems of capital utilisation. However there is least data on this autonomous hire markets in the villages because at the end of the fieldwork period farmers were only just beginning to amass enough resources to obtain their own physical capital. Even though individual farmers may have 1-4 GhC to hire a donkey for one trip it is rare that a single farmer can afford the 200 GhC for the donkey and up to 300 GhC for a cart. Indeed, of the five donkey owners encountered during the course of the study, only one had purchased both donkey and cart with his own capital and was actually a farmer living in the village.

It has been repeatedly demonstrated that one of the most crucial effects of such individual ownership was to perpetuate the traditional mode of usufruct that spread the benefits throughout the community. Such transactions, observed on many occasions, were occurring in the study communities long before *benzirugu* ownership became financially viable.

The fact that participatory group ownership divides the start-up cost between many and lowers the hire costs is the main attraction of such a solution. Even more important than this is the role of group or community social capital in acting as an access mechanism to external financial capital, which will facilitate purchase of the physical capital. In the absence of individual financial capital to pay for donkey hire or purchase an animal individually, such participatory group social capital is the only option as it has been seen that state support has not reached the village scale.

It is difficult to say whether individual or participatory ownership carries a higher risk or is a more feasible option. There is more risk of an individual owner of a hire animal becoming insolvent and being unable to maintain the cart for use. However for a group to function it requires organisational and leadership skills to motivate the members, take responsibility for group equipment and collect money. The option that provides a more reliable solution therefore depends on the coherence of the particular group compared to the wealth of the individual *benzirigu* owner. The financial capital of the *benzirigu* owner and the social capital involved in the group in some senses substitute for each other. Section 5.5 illustrated this, showing that if a farmer could pay for access to a hire vehicle he could avoid the inconvenience of having to wait for the group donkey - a great advantage considering the importance of timely practice to good SFM.

A farmers' individual stock of different types of capital determines whether they are able to purchase a *benzirigu* or take advantage of one through the hire market, and therefore whether that solution, the traditional borrowing route, or participation is most appropriate for them. If enough farmers in the community can buy individual *benzirra* and others have the financial capital to hire them, a functioning market can arise. More likely is the scenario where others use social capital to access those vehicles through the traditional route. In the absence of enough financial capital for individuals' *benzirigu* purchase, participation provides an alternative, but is only likely to occur when farmers can get together to organise it: an investment of social capital.

The nature of the good itself also affects the ease with which it can be shared - *benzirra*, partially subtractable goods, are amenable to sharing and hiring. This observation will become relevant again in Chapter six when considering the systems under which entirely subtractable goods, like fertiliser, are used.

Finally, it is instructive to confirm the scales at which these systems best operate. When asked to choose between hiring and group ownership many farmers mentioned that *any benzirigu* 'in our hand' (*'bie te nooni'*) was most attractive and prioritised the village community rather than, for example, the household or lineage. This leads to the conclusion that the availability of a vehicle *within the village* was actually more important than what type it was and whether it was owned individually, in a group or hired. Farmers stated in meetings, interviews, conversations and questionnaires that borrowing or hiring something from *within* the community was better than from outside, possibly because if an asset exists within the community, the chance that access to it may be gained through the traditional mode of begging and borrowing is higher. Overall, there was actually no clear preference for a group or an individual *benzirigu*: when asked whether they preferred using a group vehicle or their own, 42%

of farmers preferred the group and 45% preferred their own (13% stated no preference). This preference for availability within the community by any means extends to tractors as well as intermediate transport technology - a comment from Zakaria in Toonadagbogini was that if Yapalsinaa were to buy a tractor it would be advantageous as villagers would not have to travel to adjacent villages or the nearest town to hire one. Chapter two suggested that tractor carriage could provide a reasonable option for transportation of organic residues to the farm if only one were available within the study communities, and this opinion was reiterated by others repeatedly in interview, participant observation and conversation. Illustrations of how farmers prefer to use vehicles from their own community have been given: the owner of the truck hired for group farmers to use in Ypilgu retrieved his vehicle halfway through the hire period, and the Zaazi farmers declined the use of a bullock cart from an adjacent community. The farmers in Ypilgu valued the donkey being within the village to the extent that when the first donkey died in a road accident 50 of them contributed 1 Ghc (50 pence) each towards the cost of a new one. It was physical proximity and therefore *any* type of access to the large capacity *benzirigu* that mattered to farmers more than which form of access it was. Of course, farmers preferred individual or group ownership or borrowing to hiring, but preferred the fact that a *benzirigu* was available for hiring at all to not having the option to do so. The practical necessity of having access to a mode of transport overruled any ideological convictions as to where the capital for it should come from and therefore whether a traditional, statist, capitalist or participatory solution was more appropriate.

This leads to the final unsurprising conclusion. The optimum solution would be to have both hire and group donkeys available within each community. In this way those without financial capital could use bonding social capital and wait to use the group donkey in the participatory system. If it were unavailable, those with financial capital could enter the market to mobilise the hire donkey in time. The traditional system provides an indistinct area between the two where social capital is very likely to be used to gain access to a hire vehicle from within the community at a reduced rate or for a token amount. Just as a combination of different *benzirra* comprise the best transport strategy, access to capital held in diverse locations facilitates timely use of each type of *benzirigu*. In these villages, hire, borrowing and group solutions are all possible for different individuals so having a variety available would be best, reminiscent of the 'basket of options' Chambers *et al.* (1989) advocated for smallholder livelihoods. In reality, it is difficult to predict whether group or individual ownership is a more feasible option unless the characteristics of a community or the individuals within it are known. If groups can mobilise to gain access to an external source of financial capital or contribute to purchase a group object the efficiency argument for participation argues that this may be a quicker route than waiting for an individual to buy a cart that could then be hired or borrowed. But when individual capital is available for purchase and hire the social costs of group formation become unnecessary. The flexibility of the traditional system, allowing borrowing as well as hiring, means there is actually little merit of one over the other: from the farmer's point of view, whichever is more expedient is best.

5.10 Summary

Large, animal-drawn *benzirra* like donkeys and bullock carts carry most compost to the field quickly. Such timely application is probably the most crucial aspect of a successful smallholder application strategy. However, such large vehicles require similarly large amounts of financial capital to which smallholders rarely have access. Consequently, it is important for them to use a diverse system, with access to as many *benzirra* as possible to facilitate timely compost application and using as many capitals as possible to gain access to each *benzirigu*. Synergy between different modes of transport is an additional benefit of such a mixed method application strategy.

Farmers gain access to the capital necessary for large *benzirra* through two main routes. Firstly, when rich individuals can afford to purchase their own large *benzirra*, they may hire them to others. However, traditional access routes, involving begging and borrowing those large vehicles according to household and community scale obligations, are possibly the most important benefit of individual scale financial and physical capital accumulation. This system works well with less subtractable goods that can be lent.

Alternatively, if there is no capital for individual purchase of large vehicles, the participatory mechanism sees people collaborating at the community scale either to pool their resources or to get access to an external source of capital that will allow them access to a large vehicle. A social capital investment is required to effect this solution. The optimum situation is for farmers to have the option to use both these systems.

In terms of the specific technicalities of compost carriage, the wheelbarrow is very efficient but involved much effort for even a minimal number of trips so is best for carrying compost to the *sanbanni* farm. Donkeys had an advantage over bullocks in terms of their greater stamina and longer working hours. Cattle owners also preferred using a group object rather than their own cattle when the latter could be earning income from ploughing. Similarly, the donkey was chosen as the group object rather than bullocks because it was cheaper and therefore easier for the group - and therefore a private individual - to own. It is thus the most affordable and accessible high performance *benzirigu*.

Chapter five has answered the first research question, ‘What is the best way for smallholder farmers to carry compost to their maize farms and what are the capital requirements of this strategy?’, concluding that donkeys forming part of a mixed capitalist-traditional or participatory strategy could provide the most timely, and therefore best, solution to farmers carriage of compost. The extent to which each of these solutions is appropriate in a certain context will depend on the wealth of the community and the subtractability of the resource.

Chapter six will consider the same theoretical background when putting these findings into their wider SFM context. It will ask how to meet the capital requirements of the best SFM strategy.


Making compost with an extension officer in Ypilgu

Chapter Six

Soil Fertility Management

6.1 Chapter structure

Chapter five demonstrated that access to donkeys, via either or both individual ownership that facilitated traditional ususfruct, or a participatory group system, best facilitated farmers' carriage of compost to their fields. This chapter will put that finding into a wider context, answering the second research question, 'What are the comparative benefits and capital requirements of different Soil Fertility Management strategies; in particular of composts and inorganic fertilisers?' In other words, the farmers spent a season working out how to carry compost to the fields, but was it actually worth using compost at all? The first half of this chapter will explain why, for these farmers, it was. This will be done by comparing growth parameters, yields, soil nutrient levels and water retention capacities of inorganically fertilised and composted plots. The implications of these results in terms of capital requirements will be considered in the second half of the chapter. This begins by examining how farmers' capital endowments affect their ability to fertilise their crops effectively and goes on to explore the capital requirements of the various SFM techniques they use. Both halves of the chapter are brought together to assess the capital use systems necessary for farmers' access to the 'best' SFM strategies and consider how far each draws upon participatory, capitalist, traditional and statist paradigms.

6.2 Growth parameters

Forty-four farms in the experiment included a control area where no compost or fertiliser was applied, an area where compost was applied alone and an area where fertiliser only was applied. As described in Chapter four, a few did not include all treatments, either because the farmer felt they could not jeopardise yields by including a control or because they had not intended to apply fertiliser to the field they had allocated to the experiment in 2010, usually because it was a compound farm. The sample is described in terms of these characteristics in table 6.1.

Table 6.1 Number of farmers including each treatment.

Treatment	**Control**	**Compost**	Inorganic **fertiliser**
Number of farmers who applied treatment	54	59	50

Farmers supplied the compost and purchased their own state-subsidised fertilisers at 18GhC per 50kg bag of ammonia and 27 GhC per bag of compound. The rate and time of application therefore reflected their capital endowments. The growth parameters listed in Chapter four (plant height, stalk width, leaf length, days to 50% tasseling, percentage of plants yielding, cob length and cob width) were measured in each of the experimental plots. Tests for pH, C, N, P and K were also performed on soils sampled from two fallow plots to compare background nutrient levels and seasonal variation.

Interfarm comparisons of growth parameters are less meaningful due to uncontrolled variables as decisions about variety, plant spacing and weeding regime varied between farms. It would therefore make more sense to express results transformed into percentages of control values. However, plotting raw and transformed values showed the same trends, despite varying growth conditions between farms. Plotting raw values also meant more results could be included, increasing the robustness of the comparison. As not all farmers included a control plot, presenting transformed data would mean that results from some farms would be excluded, even if they had made a comparison between fertiliser and compost. Growth parameter data are therefore presented in raw form.

For all growth parameters except yield all types of inorganic fertiliser have been grouped together in a single category as the aim of this chapter is to compare inorganic and organic fertilisers. The capital requirements also vary more substantially between than within these two categories. Separating out the effects of compound 15N:15P:15K, 23N:10P:5K and Sulphate of Ammonia (hereafter 'ammonia') fertiliser generally showed that the values for each type of fertiliser fell between the values for control and composted plants, and indeed this distinction is made when yield is examined in section 6.3. Table 6.2 summarises the intrafarm comparisons between fertiliser and compost more directly than the box plots shown in figures 6.1 and 6.2, and lists the percentage of farmers for whom fertiliser outperformed compost and vice versa.

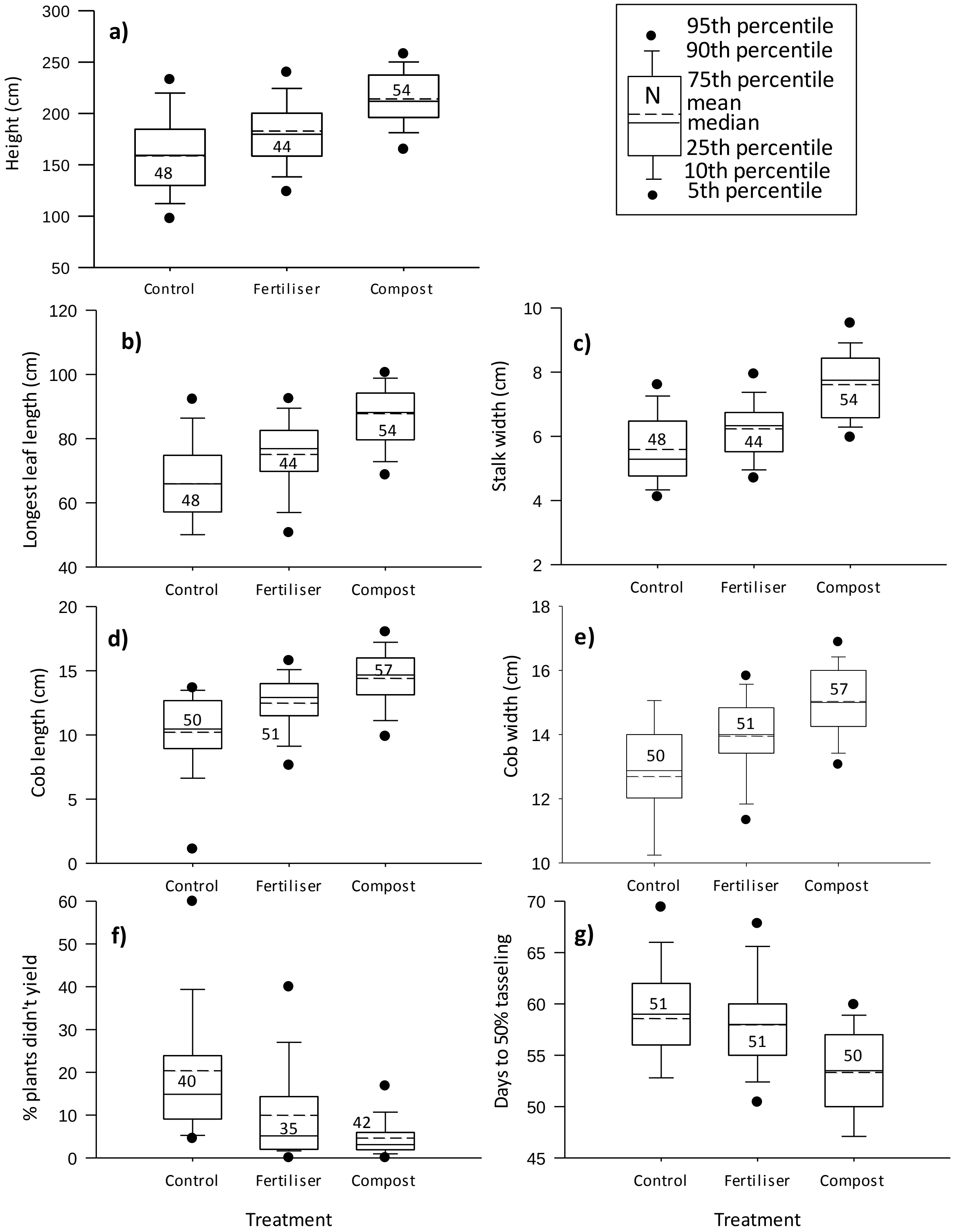

Figure 6.1 a-g Growth parameters (height, longest leaf length, stalk width, cob length, cob width, percentage barren plants and days to 50% tasselling) of maize plants in composted, fertilised and control plots. Kruskall Wallis tests showed significant differences (p<0.01) between treatments for all growth parameters measured
Note: N=Number of cases

Figure 6.1 shows that, at the rates of application farmers were able to manage, compost produces taller plants than fertiliser with wider stalks, longer leaves and more, longer and wider cobs. Composted plants tassel earlier and more of them yield. Kruskall Wallis tests showed that the difference between treatments was statistically significant for all growth parameters measured ($p<0.01$). These characteristics are generally held to be positive and representative of plant health, with just two caveats: taller plants may be more susceptible to lodging and earlier maturing plans may suffer insect and bird damage as they remain in the field waiting for harvest. However the most significant parameter for farmers is yield. This crucial statistic must be examined in further detail.

6.3 Yield

As well as comparing the results of compost and fertiliser treatments, as has been done for other growth parameters, the yield data have been arranged so that the effects of different types of fertiliser can be compared. Although many applied both, some farmers were able to apply ammonia only and some only compound. Section 4.4 described how such farmer determination of application procedure was one of the defining features of the study, making it relevant to participants' real lives. Mean yields for these treatments are displayed in figure 6.2 and a mean value for all farms where fertiliser of any type was applied is labelled 'fertiliser average'. As described in Chapter four, the families of three farmers also applied fertiliser to every single plant in their farm, meaning there was no control plot and no plot applied compost only. Although such combined compost and fertiliser application was not one of the treatments intended for consideration in the study, the data from those three farms is included in figure 6.2 for comparison - and it is valuable: the second and ISFM paradigms of Soil Fertility Management recognise that it has become clear since the 1980s that a combination of inorganic and organic fertilisers is the best strategy (Sanchez *et al.* 1996; Palm *et al.* 1997; Bationo 2009; Vanlauwe 2009).

As mentioned, interfarm comparisons of absolute yield are less meaningful due to the differences in uncontrolled variables such as variety, planting distance and weeding regime between farms. A more objective derived parameter to investigate is therefore yield as a percentage of control yield, as shown in figure 6.2 b). As this excludes some data points, calculating yield as a percentage of compost yield allows more points to be shown as in figure 6.2 c).

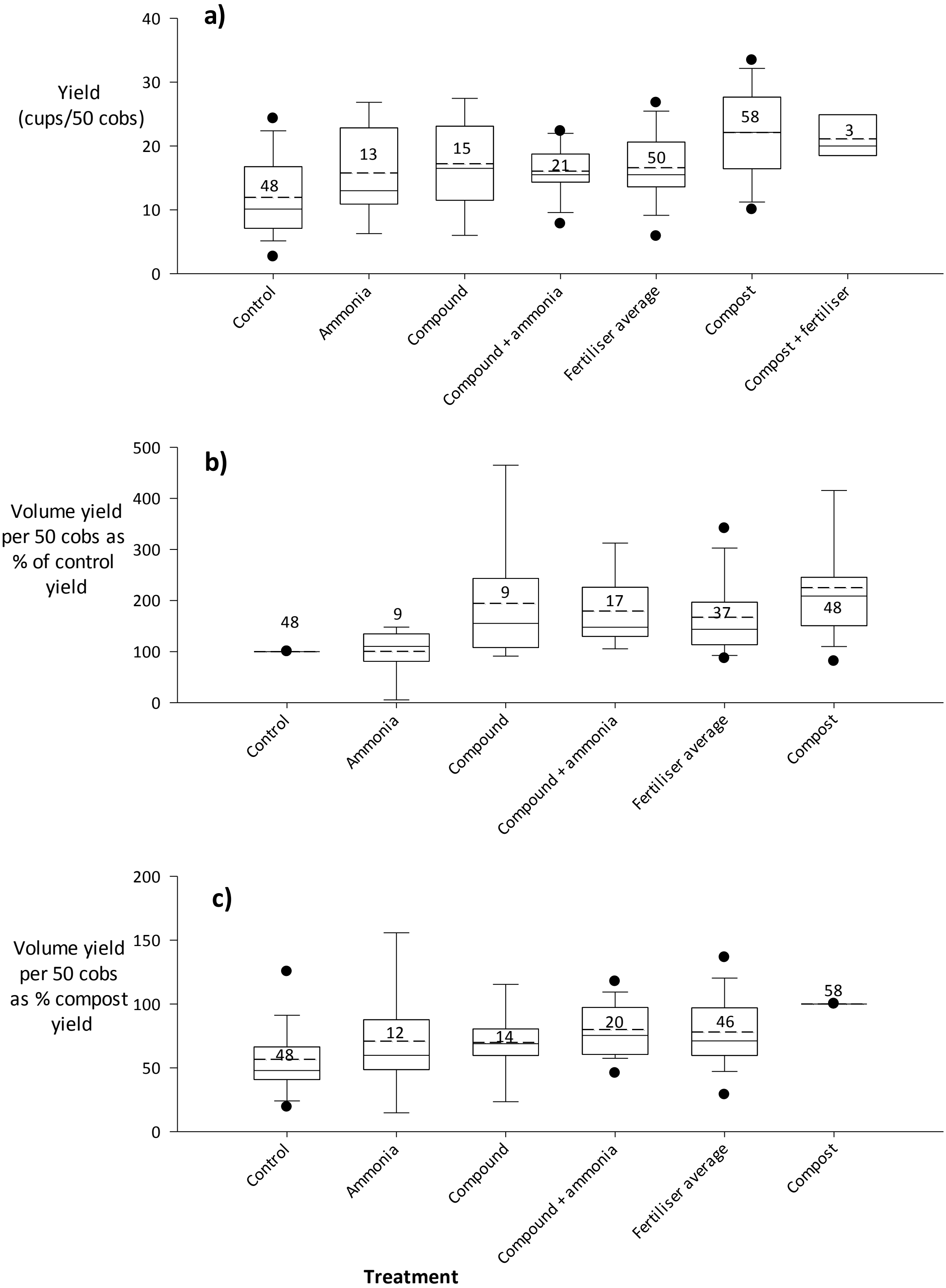

Figure 6.2 Box plot of a) absolute yield b) yield as a percentage of control yield and c) yield as a percentage of compost yield for maize plants in control, fertilised and composted areas
Note: Key as in figure 6.1

Using the different measurements of yield, and therefore slightly different data sets, means that the relative performance of compound, ammonia and both fertilisers differed between figures 6.2 a, b and c. However, ultimately, whichever measure of yield is used and whatever distinction is made between types of fertiliser applied, the data are so robust that the same trend is observed as for all other growth parameters above: compost yields were higher than those obtained using fertiliser. All the differences in mean yield between treatments were highly statistically significant ($p<0.01$ for Kruskall-Wallis tests), as they were for the other growth parameters.

It is important to note that these results show compost performing better than fertiliser *in the first year of application.* This is unusual: the benefits of compost application often become evident only in the second and third years of its application (Powell *et al.* 1998; Nyamangara *et al.* 2003). Interview data made it clear that the participants recognised that longevity of compost was one of its main advantages. Nineteen farmers explained in their first interview, and four in their second, that when compost is applied to the field the nutrients it contains continue to be released up to three years later and yield will continue to be high on the site to which it is applied. In contrast, the nutrients supplied by inorganic fertilisers are exhausted in a single season so if it is not reapplied to that site the following year the yield will be poor. Seven farmers also made the more general statement in their first interview that on an interseasonal timescale compost lasted 'longer' than fertiliser. This very important factor of longevity is a major theme in the literature as well as a primary concern of farmers (Zech *et al.* 1997).

Due to the variation in conditions between farms it is more meaningful to make an intrafarm comparison of the performance of composted and fertilised plots. Table 6.2 does this by displaying the percentage of all farms containing composted and fertilised areas in which compost performed better than fertiliser.

Table 6.2 Relative performance of farms using compost and fertiliser

Growth Parameter	Percentage of farms where compost outperformed fertiliser	N
Plant height	90.7	43
Stalk width	95.4	43
Longest leaf length	92.9	42
Cobs per plant	77.8	27
Days to 50% tasseling	94.4	36
Cob length	77.6	49
Cob width	77.1	48
Percentage of plants that yielded	60.0	35
Volume yield per 50 cobs	81.4	43

The strong advantages of compost are clear in this table. Compost plots outperform those treated with inorganic fertiliser in the majority of farms for every growth parameter, including the most important, yield. Of the 45 farmers who included compost and a fertiliser plot, fertiliser yielded more than compost for only eight of them. The qualitative data collected in the second interviews helps to explain why fertiliser did better than compost for these eight farmers, and contemplating these reasons is one of the first steps in considering how farmers' capital limitations may have a bearing on their agricultural performance. This process is begun in the third column of table 6.3. In two cases tree shade over the composted plots meant they could not meaningfully be compared to fertilised areas so they were removed from the statistical analysis.

Table 6.3 Explanations for good fertiliser performance

Farmer	Reason fertiliser yielded better than compost	Capital implications
Adam	Late preparation of compost meant it was poorly rotted so thick application led to nitrogen immobilization. Crops performed better elsewhere in the farm where compost was applied earlier. Compost was placed under trees where shade limited crop growth.	Low human capital for compost preparation. Confounding factors
Sumani	Historic application of manure to the whole field using bullock cart so high yields were not purely due to fertiliser in year of survey.	High financial and human capital.
Abdulai	Applied both ammonia and compound. Thick application of poorly rotted compost led to nitrogen immobilisation.	High financial capital. Low human capital for compost preparation.
Imogen	Had enough money to apply compound and ammonia at the right time.	High financial capital
Suleiman/ Yahaya	Applied both compound and ammonia**.**	High financial capital.
Kahsim	Compost applied under shade of tree	Confounding factors.
Abukari	Does not fit with growth parameter data – possibly sampled from area where applied compost *and* fertiliser	Confounding factors.

Having considered individual cases here it is also possible to test the whole data set statistically to see why compost gave higher yields than fertiliser for most farmers. Gachengo *et al*. (1998) summarise probably the three most important fertiliser recommendations for good yield: '(n)utrients in the right quantities, ratios and at the right time plants need them'. Interviews with farmers and conversations with MOFA Area Extension Officers (AEOs) confirmed that good yield from fertilisers usually depended on:

- Whether both ammonia and compound or just one of these two were applied - mentioned by five farmers in the qualitative section of their second interview
- Time of application - mentioned by 17 farmers
- Rate of application - mentioned by four farmers

(see also Brouwer and Powell 1995; Matson *et al.* 1997; Fowler and Rockstrom 2001; Ganry *et al.* 2001; Vanlauwe *et al.* 2001a; Nyamangara *et al.* 2003; Rufino *et al.* 2006; Gentile *et al.* 2009; Giller *et al.* 2009; Sitthaphanit *et al.* 2009)

To test the importance of these factors, statistical tests can check whether yield differs significantly between farms where farmers applied fertilisers late or early, used one or two fertilisers and used different rates of application. However with the number of observations available it is difficult to achieve a sample size that will give a robust t-test or indeed to correlate or regress yields with any of these parameters. In addition, non-normal data means that many comparisons of yield are made using non-parametric Mann-Whitney U and Kruskall-Wallis H tests. Therefore an additional useful comparison to make is whether the type of fertiliser applied, the time of application and the rate of application differ significantly between those farms in which compost outperformed fertiliser and vice versa. To facilitate such tests a new variable is computed: the ratio of compost yield to fertiliser yield. If compost yielded better than fertiliser this value is above 1.

6.3.1 Time to fertilisation

MOFA recommend that compound NPK fertiliser should be applied two to three weeks after germination to help plant growth and ammonia applied at the tasseling stage to assist cob development (Aflakpui *et al.* 2005). Phosphorous is essential for root development (Alley *et al.* 2009) and is best applied around sowing and emergence so new roots can penetrate soil and seek other nutrients and water (Chien and Menon 1995; Binder *et al.* 2000; Boyanapalle 2004; Amanullah and Zakirullah 2010). Potassium also helps to increase a plant’s resistance to disease from its emergence (Öborn *et al.* 2005). The nitrogen necessary for cob development (Thornton *et al.* 1995; Belfield and Brown 2008; Gentile *et al.* 2009), on the other hand, must be present around the time of maximum uptake and grain filling. Even if it is not applied at emergence to facilitate overall plant growth as well, Rozas *et al.* (2004) found that it can ameliorate yields even if applied just before tasselling. In the sample, few farmers were able to apply compound fertilisers containing all three macronutrients on time, i.e. by three weeks after emergence, although the majority managed to apply ammonia, a source of N alone, a week before 50% tasseling stage, as shown in table 6.4.

Table 6.4 Percentage of farmers applying compound and ammonia fertilisers by the recommended times

	Recommended application time	**N**	**Percentage of farmers who applied on time**
Compound	2-3 weeks after sowing	34	12
Ammonia	By 50% tasseling	29	69

Note: N=number of farms where farmer could give sowing and fertiliser application date

This is because a sack of ammonia, at 18ghc, is cheaper than the 27ghc sack of compound so farmers were more able to afford it. A second point some made was that as fertiliser sometimes did not arrive in the local market until May, after the first farmers had sown maize, they were unable to obtain compound in time for optimum application to the first crops. Suleimana Twahidu, who was the fifth farmer to plant maize in Ypilgu in 2010, mentioned that he had bought compound fertiliser 'in Tamale' but had not brought it to Ypilgu yet. Thus it is easier for farmers to manage timely applications of ammonia than compound because ammonia is cheaper and they have more time to accumulate the necessary capital before application becomes urgent.

The effect of timely application of compound or ammonia, however, was not strong enough to increase the absolute yield, as table 6.5 shows.

Table 6.5 Mean maize yield on plots where fertiliser was applied early and late.

	Ammonia applied 1 week before 50% tasseling	**Ammonia applied late**	**Compound applied by 3 weeks after sowing**	**Compound applied late**
Mean yield on fertilised plots (cups/50 cobs)	15.5	21.1	15.4	16.4
N	27	2	4	30
Percentage of farms where compost outyielded fertiliser	85	50	50	77

Note: N=farms in each time category with both compost and fertiliser treatments

When comparing farms where compound was applied early or late, a chi-squared test showed that plots fertilized late were more likely to have a low yield than adjacent compost plots; however this was not a significant relationship.

Considering the interfarm differences that make direct comparison between farms less robust, a more meaningful way to examine whether this common phenomenon of late application, of compound fertiliser in particular, was related to comparatively lower yields on fertilised plots, is to compare the days to fertiliser application on plots where fertiliser and compost respectively performed better, as in table 6.6.

Table 6.6 Comparison of mean days to fertiliser application between farmers whose composted crops outyielded those receiving fertiliser and vice versa.

	Mean days to compound application	**Mean days to ammonia application**
Plots where compost outperformed fertiliser	32	45
Plots where fertiliser outperformed compost	27	51

Although Mann-Whitney U tests showed that the difference was not significant, table 6.6 indicates that compound was on average applied earlier to farms where fertilised maize did better than that under compost (although the opposite pertains for ammonia).

The nitrogen important for cob formation must be available when grain is filling around tasseling time (Thornton *et al.* 1995; Rozas *et al.* 2004; Belfield and Brown 2008; Gentile *et al.* 2009), the period of maximum maize nutrient uptake (Denning *et al.* 2009); whereas the P that assists root development (Alley *et al.* 2009) should be present around sowing and emergence (Chien and Menon 1995; Binder *et al.* 2000; Boyanapalle 2004; Amanullah and Zakirullah 2010). Timely application of compound to experimental plots brought fertiliser yields slightly closer to compost yields than timely ammonia application did. Providing P and K for the whole plants' development is as important here to yield as supplying the N necessary for cob development. This indicates the importance of compost that supplies a range of micro and macronutrients. The presence of nutrients in the soil at an early stage in the plant's growth, whether from timely application of compound or compost incorporation, was as crucial to the development of high yielding cobs as an injection of nitrogen at tasseling stage. It may also be the case that nitrogen addition alone was insufficient for good cob formation because in the absence of timely compound or compost application low P and K may have limited N uptake. Inability to supply *these* nutrients early enough would then be responsible for low yields. When nutrient levels are examined in section 6.4, figures 6.3 d) and e) do imply that P and K limitation is more likely than N in these soils which are low in *all* nutrients. As P and K, more so than N, must be applied early in a plant's life cycle, the importance of timely capital availability and utilisation is once again highlighted.

In order further to examine the influence of the timing of fertiliser application the farms were divided into two groups – those who applied all fertilisers on time and those who applied any fertiliser late. However neither absolute yield nor yield as a percentage of control or compost values was significantly different between these groups.

Just over 20% of the farmers who managed to apply all fertiliser on time achieved higher yields from their fertiliser than from compost compared to 15.6% of the farmers who applied fertiliser late. However a chi-squared test showed that this was not a significant difference so again the most telling statistic is actually that the majority of farmers, whether they applied on time or not, had higher compost than fertiliser yields.

In general the data on fertiliser application time indicates that if there is any effect, late application of compound fertiliser is more likely to be responsible for low maize yields than late application of ammonia. Another possible reason for low yields which is not accounted for in these tests is that many farmers applied just one rather than two fertilisers, so the next section will examine how the number of fertilisers applied affected yield.

6.3.2 Number of fertilisers applied

The optimum situation would be application of both compound and ammonia fertilisers to *puuni* farms outside the fertile homestead band. However table 6.7 shows that only 63.5% of farmers achieved this across their farms. This does not exclude the possibility that even on those farms where compound and ammonia were applied they could have been applied on different fields. The statistic drops to 37.5% within the experimental farms. This was because many farmers allocated *sanbanni* farms to the experiment, which were targeted with compost and did not receive a fertiliser treatment.

Table 6.7 Number of farmers applying each fertiliser treatment

Treatment	No fertiliser	Ammonia only	Compound only	Ammonia and compound
Percentage of 52 farmers in sample applying this treatment anywhere in all their farms	5.8	13.5	17.2	63.5
Percentage of 56 farmers in sample applying this treatment anywhere in their experimental farms	25.0	14.3	23.2	37.5

Table 6.8 shows that mean yield was slightly but, according to Mann-Whitney U test, not significantly higher in those farms where two, as opposed to one, fertilisers were used.

Table 6.8 Yield comparisons between farmers who applied different fertiliser treatments

Treatment	Ammonia	Compound	Just ammonia or just compound	Ammonia and compound
N	7	12	19	16
Mean yield (cups/50 cobs)	13.2	18.0	16.3	16.7
Percentage of farms where compost outperformed fertiliser	71.4	83.3	78.9	84.2

Note: N=Number of farms that performed each fertiliser treatment and compared fertiliser to compost

This confirms that maize plants do perform best when the whole range of macronutrients is applied, and is confirmed by the results of other studies. Jiang *et al*. (2006) found maize fertilised with NPK yielded better than that given a treatment of N and P or N alone. Both Nels *et al.* (1996) and Wopereis *et al.* (2006) observed that combinations of N and P performed better than sole application of either, especially P. Nels *et al*.'s study also included K, the addition of which raised yields above those obtained from an NP treatment. Vanlauwe *et al.* (2006) saw NPK treated maize yielding better than that given just two elements, even though response to K was not as strong as to N or P.

Harder to interpret is the result that maize given just ammonia more frequently outyielded adjacent composted plots than that given other fertiliser treatments. Which nutrient the farmer needs to supply depends upon which is limiting in the particular site (Goldsworthy 1967). However, it is unlikely that N alone is lacking in the study area: the response to P and K was indicated by the positive effect of early compound application and corroborated by the soil tests to be displayed shortly in figure 6.3. It is possible that as farmers who apply ammonia almost always do so at tasselling period, this timely nitrogen input at grain filling stage raised their yields over those who applied compound close to emergence, risking N leaching and loss between then and the period of maximum uptake.

Another explanation emerges upon examination of the respective yields of compost and fertiliser plots. This shows that the compost yields of plants on farms where two fertilisers were applied were so much higher (up to 32 cups/50 cobs) that they more often outyielded the adjacent maize applied with two types of fertiliser. Those farmers who could afford to apply two types of fertiliser also had enough capital to apply a lot of compost. Although differences were not significant, comparison of means showed that these farmers' mean compost application rate was higher than those who applied just compound, and those who applied just ammonia lagged furthest behind. This is a good illustration of the interplay between agronomic and socioeconomic factors in explaining the effects of farmers' practice. When the fertiliser yield data are viewed holistically and contextualised by the data relating to compost application its larger significance becomes apparent: once again the most important point is that compost usually outperforms fertiliser no matter which combination of inorganic macronutrients is used.

Within this data set the differences in yield between treatments combining different inorganic nutrients are less important than whether the nutrients supplied are from organic or inorganic sources. This is possibly because whichever fertiliser the farmers used, they did not apply it in sufficient quantity. The rate of fertiliser application will therefore be examined next.

6.3.3 Rate of fertiliser application

Table 6.9 shows the percentage of farmers who used compound and ammonia who applied these fertilisers at the rates recommended by MOFA.

Table 6.9 Percentage of farmers applying fertiliser at recommended rates

	Recommended rate (kg fertiliser/acre)	N	Percent applying at recommended rate	Mean rate (kg/acre)
Compound	100	33	9	51
Ammonia	50	28	46	43

Note: N =Number of farmers able to give application rate of each fertiliser

As with time of application, more farmers were able to follow MOFA application rate recommendations for ammonia than compound. This again can be directly related to financial capital - at 18Ghc/acre recommended application of ammonia is a third of the cost of that of compound, at 54Ghc/acre.

Table 6.10 shows that yield on fertilised plots was slightly higher for those who applied fertilisers at the recommended rates than those who did not, although this difference was not significant for compound or ammonia.

Table 6.10 Fertiliser yields of farmers who applied fertiliser at different rates

	Ammonia applied		Compound applied	
	at recommended rate	**below recommended rate**	**at recommended rate**	**below recommended rate**
Mean yield on fertilised plots (cups/50 cobs)	17.7	14.0	16.7	16.2
N	12	15	3	27
Percentage farms where compost outperformed fertiliser	67	87	66	85

Note: N=number of farms in each application rate category applied with fertiliser and compost

More representatively, when fertiliser was not applied at the recommended rate, maize plants on adjacent composted plots more often outperformed those fertilised inorganically than was the case when fertiliser was applied at the recommended rate. In agreement with this, table 6.11 shows that rate of both compound and ammonia application was on average higher for farms where fertiliser outperformed compost, although again this difference was not significant for compound or ammonia.

Table 6.11 Fertiliser application rates for farms where fertiliser outperformed compost and vice versa

	Mean compound application rate (50kg bags/acre)	**Mean ammonia application rate (50kg bags/acre)**
Plots where compost outperformed fertiliser	0.93	0.73
Plots where fertiliser outperformed compost	1.37	1.0
N	30	27

The rate at which fertiliser is applied has a greater effect upon yield than the time of application or which combination of fertilisers is applied.

The MOFA recommended dosage of two sacks or 100 kg acre^{-1} 15N:15P:15K compound fertiliser supplies 37g N ha^{-1}, P_2O_5 ha^{-1} and K_2O ha^{-1}. For ammonia, the recommended one sackful or 50 kg acre^{-1} ammonia fertiliser supplies 25.9 kg N ha^{-1}, making a total MOFA recommendation of 62.9 kg N ha^{-1} (see Appendix 10 for calculations). Maize in optimum temperate conditions removes 160 kg N ha^{-1} and application of up to 85 kg P_2O_5 ha^{-1} is recommended (PDA 2008). In the suboptimum moisture conditions of the savanna, growth and therefore nutrient uptake is potentially less. Although fertiliser trials are rare in tropical countries because they are costly (Osmond and Riha 1996), there are some data that can be use for comparison. Amanullah and Zakirullah (2010) found maize yields rose from 1666 to 2164 kg ha^{-1} in semi-arid Pakistan as they increased P application from 30 to 90 kg P ha^{-1} (equivalent to 137 and 412 kg P_2O_5 ha^{-1}). As Adediran *et al*. (2005) raised levels of NPK 20:10:10 fertiliser in llora, Nigeria from 0 to 100 kg N ha^{-1}, maize yields rose from 920 to 2800 kg ha^{-1}, and a similar effect was observed for compost at application rates up to 10 t ha^{-1}. In the Togo coastal savanna, maize responded to increases in N fertilisation up to rates of 100 kg N ha^{-1} before limitation that Fofana *et al.* (2005) ascribed to water stress. All these studies applied nutrients at levels above MOFA recommendations and still saw responses from maize. Only 9% and 46% of farmers in the study area reached MOFA compound and ammonia target application rates. It is therefore very likely that maize will respond to any nutrient input they make, but also that they will be unable to achieve the maximum nutrient input levels that result in the greatest maize response.

However, once again, the statistic of most importance is that regardless of how much fertiliser they put on their farms, compost outperformed fertiliser for the majority of farmers.

Most farmers in the study area are using less than the recommended amount of fertiliser, just as they are supplying fertiliser late and not in the recommended combinations. This is one reason why the current ISFM paradigm recommends combined application - farmers lack the financial and infrastructural resources to follow inorganic fertiliser application guidelines, so must obtain nutrients from organic amendments in addition. If this is so, it could be construed that financial capital is limiting almost *everyone* in the sample and this is why statistical tests do not always discern difference between groups of farmers, as seen in table 6.5 above, where the effect of applying compost early was not sufficient to increase the mean yield on farmers' plots. However, compost outperformed fertiliser even for many of those who applied fertiliser at the right rate, applied two fertilisers rather than one and applied them at the right time. If macronutrient supply alone was limiting maize production, application of two fertilisers at higher rates and on time should always result in maximum yields. As getting adequate inorganic nutrients to the plants on time does not always help them to perform better than when they are treated with compost, it is likely that there are also added unmeasured benefits of compost - e.g. improved soil structure, micronutrients, soil fauna and organic matter addition - that are responsible for the better performance of composted maize. This resonates with Vanlauwe *et al.'s* (2001b) indirect hypothesis for mechanisms behind the synergies observed in mixed applications.

Two pieces of evidence allow investigation of this hypothesis. Firstly, soil sampling facilitates the comparison of C, N, P, K and pH levels between the treatments and assessment of whether macronutrients are present in sufficient quantities or are limiting growth. Secondly, some of the other possibly limiting factors can be investigated. It is more difficult to measure quantitatively some of the qualities which differ between inorganically and organically fertilised soils, such as friability, soil biota and texture. Carbon analysis is one method which was pursued and qualitative observations of the difference in soil quality were made between composted and non-composted sites, noting the darker colour and occasional algal growth in composted soils. To address one of the most important benefits of organic matter, a soil water retention assay was performed in May 2010. The results of this assay are presented after the soil nutrient tests.

6.4 Nutrient tests

The first set of tests was performed at the sowing period in May-June 2010. Samples were taken from composted and control plots in 30 farms as well as from two permanently fallow plots on sites where farming was taboo, one in each of the two villages. One of these was an ancient battleground and one simply described as '*tambiegu*' or 'bad land'.

As described, farmers applied compound fertiliser three to four weeks after planting and ammonia at the tasseling stage. A first sample was taken in the fertilised plot of one farm three days after compound fertiliser application. This was the only farm where the farmer had sufficient financial capital to apply fertiliser at this stage. The second sample was taken in all farms as close to 50% tasseling as possible once ammonia had been applied. All farms were sampled for a third time after harvesting, between September and October 2010, and finally a fourth round was performed a year later in May 2011.

Results of the C, N, P, K and pH analyses performed on these samples are shown in figure 6.3.

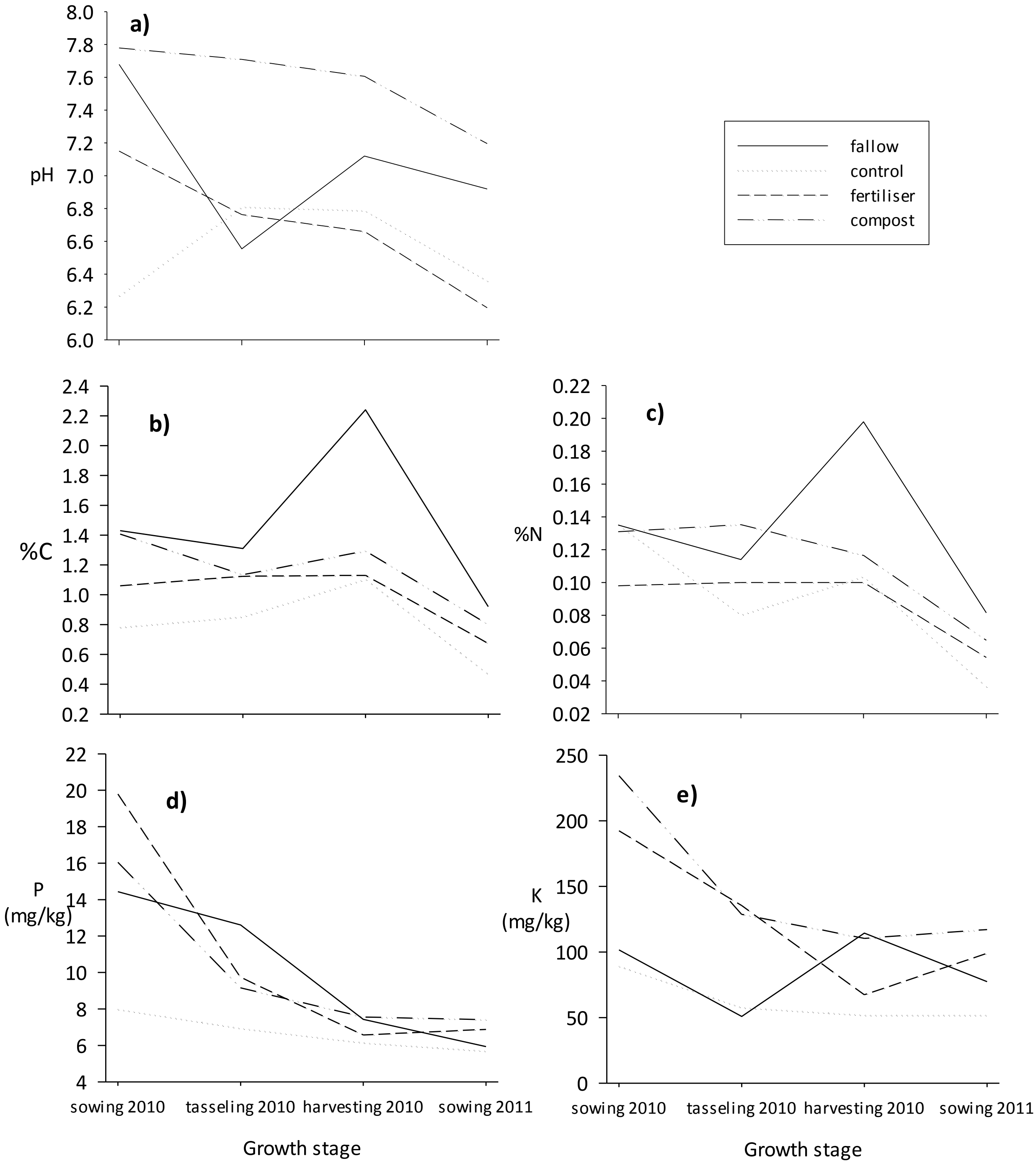

Figure 6.3 Mean pH (a), C (b), N (c), P (d) and K (e) values over the 2010-11 season.

Unsurprisingly, at the sowing stage, C, macronutrient and pH levels were always higher in composted than control plots, and Mann-Whitney U tests showed that these differences were significant ($p<0.01$) for all parameters measured.

However, as for the yield results discussed earlier, intersite heterogeneity means that a more meaningful measure of difference is to compare the percentage of farms where composted plots outperformed controls and fertiliser. In the case of soil samples, intersite heterogeneity is a particularly relevant concern, as both villages were represented in the sample. In this first sampling round, 100% of composted plots had higher nutrient and pH levels than the controls from the same farm. These levels were comparable to the two fallow control plots and higher in the case of K.

Before analysing specific nutrient levels at different time points, the shapes of the curves give an idea of the background soil nutrient levels. The nutrient trends over the whole season resonate with the results of section 6.3.1 that indicated low background levels of soil P and K were probably responsible for the importance of early compound fertiliser application. Fertiliser and compost P and K levels are very similar when compared to the intraseasonal range. Phosphorous may be sorbed and fixed to iron and aluminium oxides and oxyhydroxides in savanna soils (Bationo and Mokwunye 1991a; Buresh *et al.* 1997) or locked into $Ca\ PO_4$ (Agbenin 1995), but immediately after application it is available in soil solution and is taken up by plants, hence the sharp drops in its concentration over the season. Although, like P, it can occasionally sorb to kaolinite edge sites (Agbenin and Yakubu 2006), K is more soluble and therefore easily lost through leaching. This is especially the case in the kaolinite-dominated tropical soils of the study area, where there are fewer of the interlayer sites found in 2:1 clays in which K may be trapped and fixed into the non-exchangeable nutrient pool (Wild 1971; Öborn *et al.* 2005), especially during wetting and drying cycles (Zeng and Brown 2000). The K supplied by fertiliser and compost at sowing is therefore rapidly taken up by plants or lost through leaching. Yawson *et al.* (2011) found that the Kpelesawgu series that probably dominates in the study area held K poorly in comparison to nine other Ghanaian soils, despite the general propensity of savanna soils to hold K better than those from the forest zones. This limited availability of P and K in the study site explains why section 6.3.1 saw that early, sufficient application of compound fertiliser was especially important for good maize performance here.

In contrast, the flatter curves of the N graph show that maize has been better able to obtain the necessary levels of this nutrient. Soil-water and atmospheric sources could have brought some N into the system (He *et al.* 2010; Böhme *et al.* 2003), but compost and fertiliser probably contributed significant amounts. The rises in C and N in the fallow plots may represent nutrients immobilised into microbial biomass or mineralisation of topsoil residue (Singh *et al.* 1991) by microorganisms active during the warm wet growing season (Isichei and Muoghalu 1992), or grazing of microbial biomass by soil macrofauna (Singh *et al.* 1989). This may also explain the smaller rise in N in control plots over the season, although here much of the N has been taken up by growing maize plants. In the control plots P and K limitation may also mean plants are unable to take up all the N as they have in the compost and fertiliser sites, hence the small residual amounts remaining in the soil. Some of the nitrogen made available in fallow plots would be used by grasses which reach maturity around two months after maize harvesting. When the new season's grasses begin to grow the following April, C and N levels decline further until the following seasons' microbial activity makes more available.

All plots showed rises in C as well as N between tasseling and harvesting period. Additional C may have been incorporated into the soil during weeding in the experimental plots and leaf litter degradation in the fallows. As an indicator of the level of organic matter in the soil, organic carbon at between 0.8% and 1.4% shows that soils are poor in organic matter all year round. The importance of that organic matter rather than macronutrients alone is highlighted by the analysis of relative nutrient levels at tasseling, harvest, and second sowing periods.

When the results from the tasseling stage are scrutinised to see if they can explain the better yields obtained on composted plots, the difference between fertilised and composted plots is not so acute. When absolute levels of nutrients are compared between all four treatments in Kruskall-Wallis tests, fertiliser has significantly higher P and K levels and compost a significantly higher pH. Comparing the fertiliser and compost treatments alone using Mann-Whitney tests, only the difference in pH remained significant, indicating that compost and fertiliser treatments provide similar levels of the important P and K. Interfarm differences could have confounded the results to some extent, so, to make nutrient levels comparable, values from compost and fertiliser plots were recomputed as a percentage of the control plot values (except for pH which is on a logarithmic scale). When this was done the results remained the same - there was no significant difference in macronutrient levels between compost and fertiliser plots at tasseling stage.

Table 6.12 presents the data in a way that accounts for interfarm differences by showing the percentage of farms where nutrient levels are higher on plots treated with compost than those treated with fertiliser.

Table 6.12 Percentage of farms where composted plots had higher nutrient values than those where fertiliser was applied at tasselling stage.

Parameter	**Percentage of composted plots that outperform fertiliser at tasselling**
pH	89.7
C	51.8
N	48.3
P	51.7
K	48.3

This table confirms that, at tasseling stage, compost consistently outperforms fertiliser only in the case of pH.

If only pH was significantly different between composted and fertilised plots at tasseling stage, why was yield on compost plots significantly higher? Fertilised plots have very slightly more advantageous P and K levels than compost at tasseling but the differences are not statistically significant. If these nutrients are limiting and supplied in greater quantity by fertiliser the yields from this treatment should be higher than with compost alone, whereas compost in fact gives significantly higher yields. Higher P and K levels given by compost at sowing could be part of the answer. Considering the data above showing that macronutrient levels are not significantly different between treatments at tasseling stage, it is reasonable and safe to conclude that other non-nutrient qualities of compost were also responsible. One such quality is the difference in pH seen in figure 6.3 a). Compost has a significantly higher pH than fertilised and fallow plots. As mentioned, pH is a logarithmic scale so a rise of 1 unit means a thousand-fold decrease in the concentration of hydrogen ions in soil solution. Higher pH lowers the availability of anionic micronutrients and boron and raises that of molybdenum (Brady and Buckman 1974; Foth 1990). This effect is, however, unlikely to be limiting close to neutral pH and will not greatly affect yield. A more likely mechanism is the positive effect of higher pH on soil biota, the subsequent opening of soil structure due to bioturbation and aggregation (Haynes and Naidu 1998; Ayuke *et al.* 2011) and resultant enhanced soil moisture retention. Soils treated with compost also have a slightly higher C level than fertiliser, indicating their high OM content. As compost and fertiliser treatments raise C to similar levels it seems unlikely that this is directly responsible for higher compost yields. However C is not strictly itself a nutrient and in this context acts as a proxy for SOM. Small differences in percentage carbon content represent larger differences in the total percentage of SOM, which contains other elements as well. There may therefore be significant differences in the many beneficial properties of SOM. Amongst these, micronutrient availability is increased (Sivakumar 1992) and sorption of chemicals to the organic matrix can both immobilise toxins and metals and store inorganic nutrients for delayed release (Coyne 1999). This may enhance nutrient use efficiency (Nyamangara *et al.* 2003; Mugwe *et al.* 2009).

Another way nutrient use efficiency may be enhanced is when other limiting factors are alleviated, invoking Vanlauwe *et al*.'s (2001b) indirect hypothesis explaining the beneficial effects of combined application. Like higher pH, organic matter raises levels of biological activity as it is a substrate (Goyal *et al.* 1999; Settle and Garba 2011). As well as bioturbation, biological production of humic compounds can increase the stability of aggregates encouraged by high levels of organomineral complexes and organic exudates. This improvement of physical conditions allows more airflow to maize roots and means growing tips can more easily penetrate the soil (Hati *et al.* 2006). Most importantly, soil water retention is improved. When such limiting conditions are alleviated it may be easier for plants to take up nutrients. The importance of good soil structure and water retention is emphasised in the literature as much as that of early P and K availability, and was mentioned by farmers and experts as critical in the unpredictable rainfall pattern of the savanna (Rawls *et al.* 2003).

As already established, another major benefit of compost is its longevity compared to inorganic fertilisation (Powell *et al.* 1998; Nyamangara *et al.* 2003). This was mentioned by just over half of farmers in their first interview. Measuring nutrient levels at harvest time as well as the following sowing period indicates the effect of the different treatments over the longer term. Both these measurements are necessary because biological transformations in the soil over the dry season will alter the amount of nutrients present by the onset of the next rains. For C, P and K more or less the same transformations would occur in all plots in a field, but N may be present as nitrate, ammonia or another organic compound, depending on which biological processes occurred during the growing season as a result of different soil biota in composted and non-composted soil. Each of these N compounds could be further transformed via different routes and therefore could be differentially available at the start of the growing season. It is therefore particularly important to sample plots in the following season as well as at harvest to see how much N has been lost.

At harvesting period, Kruskall Wallis and Mann-Whitney tests showed that pH and P and K levels were significantly higher on compost than fertiliser plots. Column 2 of table 6.13 also shows that nutrient levels were higher in composted than fertilised plots in a majority of farms.

Table 6.13 Comparative nutrient levels in composted and fertilised plots at harvesting and 2011 sowing

	Percentage composted plots outperforming fertiliser at harvest	**Percentage composted plots outperforming fertiliser at 2011 sowing**
pH	92.9	92.2
C	64.3	66.7
N	67.9	66.7
P	82.1	66.7
K	82.1	66.7

It could be construed from these data that that the higher levels of the limiting P and K compost provided were responsible for its better interannual performance. However, data from the 2011 sowing period in column 3 of table 6.13 showed that by that point, compost had less advantage over fertiliser. More importantly, Mann-Whitney tests showed that differences between compost and fertiliser were not significant. Compost also had significantly higher levels of N rather than P and K in Kruskall-Wallis tests, although pH still remained significantly higher. So although compost still had a slight nutrient advantage over fertiliser it was not strongly evident that it was especially important for provision of the limiting P and K.

Most importantly, the overall levels of nutrients in 2011 did not approach the levels seen at the previous year's application period, confirming that macronutrient provision was not the major reason for the superior interannual performance of compost that was observed in the field and claimed by farmers in interview. The benefits deriving from higher pH described above are more likely to be responsible for the majority of that effect. In particular, field observations indicate that the nutrient retention effects of better soil structure dominate. Figure 6.4 shows that maize plants positioned on old compost sites demonstrate characteristics typical of higher nitrogen levels: taller plants, bigger cobs and in particular darker green leaves.

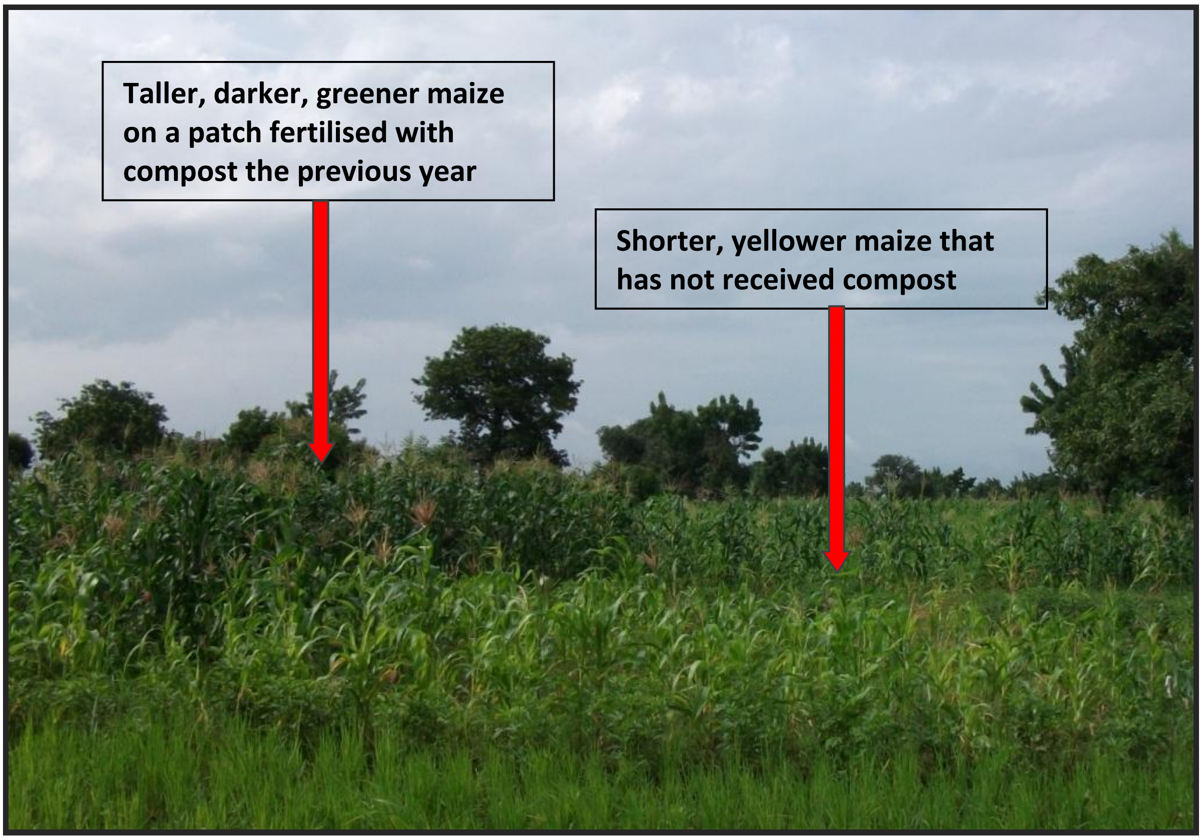

Figure 6.4 Maize on a year-old compost site

Slightly higher nitrogen levels were seen in formerly composted plots the following year, but as those levels did not approach those of the previous year, retention of intraseasonal aqueous nitrogen transfers by more porous soil may be one of the important effects of better soil structure. This would be due to the enhanced water retention capacity of soil with better structure, the focus of section 6.5.

6.5 Soil water availability

The preceding section shows that as compost did not preferentially supply any macronutrient at tasseling stage, its non-nutrient benefits were likely to be responsible for high yields. It has been suggested that soil water holding capacity is likely to have been very significant amongst such properties. This is backed up by qualitative data from farmers, who regarded the increased water holding capacity of the soil a major benefit of compost. Just over a quarter of the 59 farmers who were interviewed in depth described how soil amended with compost retained rainwater for longer than soil to which no compost had been added. Further comment on this phenomenon revealed that this allowed plants grown in composted-amended soil to withstand drought better, as after about a week the differences in water holding capacity between the two treatments would become evident. Four farmers explained in detail how this was because compost made the ground 'softer' so that the foot would sink into soil whereas soil fertilised with mineral fertiliser would remain hard and compact, i.e. the bulk density of composted soil would be lower and pore space higher. An experiment carried out to test whether soils with higher application of organic matter retained rain water more effectively bore out the farmers' observations.

Soil was sampled immediately, six days and 11 days after rain from 30 *sanbanni* and 30 *puuni* farms, the former acting as a proxy for soil amended with compost and the latter for that without (following Wopereis *et al.* (2006)). A Mann-Whitney U test found that soil bulk density was significantly higher for *puuni* sites ($p<0.05$).

Moisture content by weight was recorded on each sampling occasion and the moisture loss at six and 11 days calculated. Figure 6.5 shows the significantly different ($p<0.01$) mean water contents for *sanbanni* and *puuni* sites one, six and 11 days after rain and table 6.14 displays the absolute and percentage water loss in *sanbanni* and *puuni* sites for the same assay, which were also significantly different ($p<0.01$).

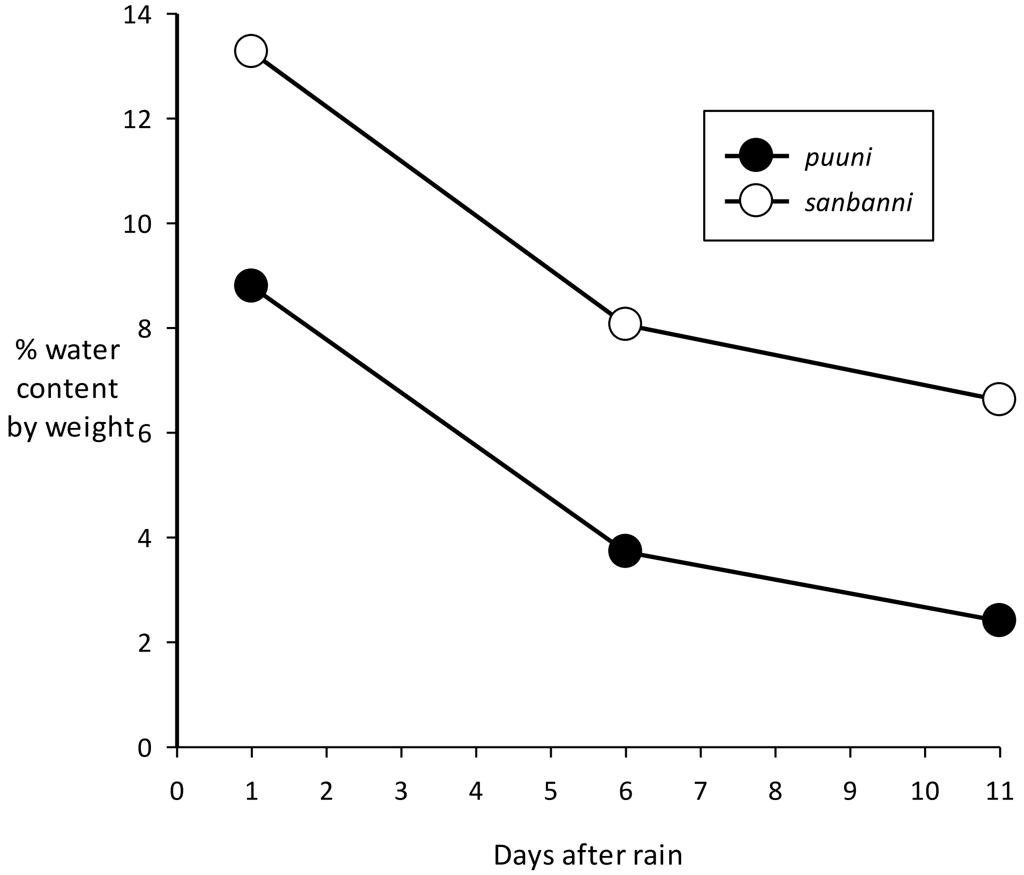

Figure 6.5 Water content of *sanbanni* and *puuni* farms up to 11 days after rain.

Table 6.14 Water loss from s*anbanni* and *puuni* farms after rain.

Parameter	***Sanbanni* mean**	***Puuni* mean**
Percent soil water content 1 day after rain	13.3	8.8
Percent soil water content 6 days after rain	8.1	3.7
Percent soil water content 11 days after rain	6.6	2.4
Percentage change in soil water content after 6 days	41.3	56.9
Percentage change in soil water content after 11 days	53.9	72.5

Sanbanni farms, due to their significantly lower bulk density, absorbed more water immediately after rain and retained a significantly higher percentage of this water over the 11 days of the assay. They actually lost a slightly higher absolute amount of water over the 11 days but due to the higher initial absorption retained more soil moisture at the end. This improved water retention capacity is one of the non-nutrient benefits of organic matter incorporation and is likely to be a major factor responsible for the higher yields of maize fertilised with compost. Like most of the literature, Wopereis *et al*.'s (2006) results agree with those found here. In a study that similarly used infields and outfields as proxies for organic matter content, they ascribed greater yields on compound farms in Northern Togo to raised soil organic matter content and thus to better water retention. Agele *et al*. (2005) amended sites with manure and NPK, finding that the water retention capacity of the manure-amended sites was higher (0.14 and 0.15 g g^{-1}) than those amended with inorganic nitrogen (0.11, 0.12 and 0.12 g g^{-1}). Vanlauwe *et al*. (2001a) ascribe higher maize yield of combined treatments of urea and organic matter than urea alone to this mechanism, although they could not discount the possibility that enhanced nutrient efficiency may have resulted from high quality residues. In Burkina, Zougmoré *et al*. (2005) combined the soil and water conservation techniques of stone bunding and grass strips with urea and compost. When the compost treatments yielded more than those given fertiliser they ascribed it to superior nutrient provision, but another reasonable interpretation they did not consider is that compost improved soil structure and water conservation more than urea.

The better water retention capacity of soils amended with organic matter is especially important in the unpredictable rainfall regime of the savanna. Appendix 11 shows the rainfall pattern between 2007 and 2011. Periods of up to six days without rain between June and September - the maize growing season - occur 15 times over the 5 year data set. As the results show that after six days the water retention capacity of composted plots outperforms non-composted plots these benefits of organic matter incorporation are useful to farmers at least thrice in a season.

The effects of technical aspects of the methodology should be considered: one of the problems with using *sanbanni* sites as a proxy for composted patches is that they are more vulnerable to wetting from sources other than precipitation, like washing water and animal urine. Soil in the compacted condition of the dry season is also not truly representative of the ploughed, disturbed soil of the rainy season. However there was no alternative to this method, as in the rainy season it is impossible to predict when a week without rain will occur so the assay could not have been performed then. These methodological points highlight again the difficulties of working - and farming - in an unpredictable rainfall regime.

This section has ascribed the significantly higher soil water retention of *sanbanni* than *puuni* sites to higher SOM content. Section 6.4 considered that as organic matter contains elements other than C, the small differences in C between compost and fertiliser sites could indicate larger differences in organic matter sufficient to bring about the differences in water retention, and hence yield, demonstrated here and in section 6.3. Such an effect relates to Vanlauwe *et al.*'s indirect hypothesis, explaining how non-macronutrient mechanisms can alleviate constraints to the uptake of N, P and K in combined applications. This study refers to the sole use of compost, but the mechanism through which the beneficial effect occurs is the same: amelioration of non-macronutrient soil constraints.

The addition of P and K at sowing had some positive effect on yield, one that could be provided through the use of financial capital for compound fertiliser purchase or through compost application. But more importantly than the economic constraints that prevented farmers applying fertiliser on time and in sufficient quantity, there are benefits to the use of compost that inorganic fertiliser can never supply. Compost probably gave higher yields because of its non-macronutrient advantages, specifically water retention and pH effects, meaning that it has a unique role to play in terms of improving soil physical properties. This confirms the relevance of strong sustainability. The capital constraints upon farmers' use of compost explored in Chapter five are therefore probably more critical for their output than the constraints upon their fertiliser use and may therefore be a more relevant target to channel their limited financial and physical capital towards. This, however, should be within the context of a combined organic and inorganic input strategy, as the importance of external inputs is recognised in the light of the data that compost does not supply higher nutrient level at tasseling (Palm *et al.* 1997; Bationo 2009; Vanlauwe 2009). Overall, the results support more Sanchez's 'second' paradigm of Soil Fertility Management, and its LEISA informed recommendation of 'minimal' application of fertilisers and maximum internal cycling, than ISFM in the paradigmatic sense, with its emphasis on market integration and subsidy to encourage fertiliser use.

Farmers in the study area, as across West Africa, do successfully practice a range of such fertilisation methods. Having drawn conclusions about the relative agronomic benefits of each of these, the study can turn to focus in more detail on their capital requirements. It was noted in section 6.3 that inability to access enough financial capital on time limits access to fertiliser, most critically compound. It is therefore useful to refer back to this section to see whether there was a relationship between farmers' wealth and their application of compost and fertiliser. This will lead into a more detailed consideration of the different capitals required for each fertilisation strategy and therefore which are indeed most viable.

6.6 Capital and soil management practices

The analysis of how SFM practice relates to capital begins by revisiting the three factors identified in section 6.3 as elements of good fertilisation practice: timely application of two rather than one fertiliser at the recommended rate. This was performed in a similar process to that carried out in section 5.7, where seven indicators of farmers' capital endowments derived from the census were statistically related to the volume and rate of compost they could carry. Here, chi-squared tests showed that there were no significant differences between poorer and richer farmers in terms of whether they applied one or two fertilisers, but some applied fertilisers significantly earlier. Non-parametric Mann Whitney and Kruskall Wallis tests showed that although there were also no significant differences between poorer and richer farmers in terms of whether their composted and fertilised crops yielded better, there were some differences in compost and fertiliser application rates for farmers with different wealth characteristics. The significant relationships are shown in table 6.15.

Table 6.15 Significant relationships between wealth indicators and fertilisation practices

Wealth indicator categories	Compound application rate	Ammonia application rate	Compost application rate	Fertiliser applied on time
Livestock ownership	/	/	/	** 1
Access to bikes	/	/	**2	/
Benzirra in house	** 3	**4	/	**5
Number of wives	/	*6	/	/
Cattle in house	/		*7	*8
Other income	*9	/	**10	**11

Notes: /=No significant relationship, *=p<0.001, **=p<0.005, numbers indicate significant relationships and are further explained below.

1 Those with more livestock more likely to apply ammonia on time (X^2=7.508, df=2). *
Categories: a) less than 10 fowl, b) 10 fowl or 1 small ruminant, c) 10 small ruminants or 1 cow.
2 Those with better access to bikes apply less compost (H=253.0, N=63).
Categories: a) no bike but helper has bike, b) have own bike, c) they and 3 helpers have bikes.
3 Those with *benzirra* in house apply more compound than those without (U=31.5, N=68).
4 Those with *benzirra* in house apply more ammonia (U=29.5, N=68).
5 Those with *benzirra* in house more likely to apply compound on time (X^2 12.34, df=1).
6 Those with more wives apply more ammonia (H=8.2, N=67).
7 Those with cows in house apply less compost than those without (U=340.0, N=65).
8 Those with cows in house more likely to apply ammonia on time (X^2=4.971, df=1).
9 Those with an income other than from farming applied most compound (H=7.719, N=65).
Categories: a) no income other than from farming, b) cash vegetable production, c) other income.
10 Those with an income other than from farming applied most compost t (H=20.613 N=65).
11 Those who grew cash vegetables more likely to apply ammonia on time (X^2=12.180, df=2).

All the significant relationships show richer farmers were able to apply higher rates of fertiliser on time but also that they applied less compost. For some this last could be because they spent their money on inorganic fertiliser rather than forms of transport to carry the compost to the field, although it is a surprising result as section 6.3.2 illustrated the observation often made in the literature that wealthier farmers are more likely to carry out a range of fertilisation techniques: there is no dichotomous choice between fertiliser and compost (Chianu and Tsujii 2005). Section 6.3 also showed that farmers' application of fertiliser earlier and at a higher rate did not always significantly raise yields across the sample, as few were able to fully carry out the recommended practices and fertilisers could not supply the non-nutrient benefits such as water retention that raised yield. Section 6.3.1 indicated that early application of P and K from compound fertiliser and compost was especially important in this savanna environment. It is therefore especially pertinent to note that compound application rate and time to compound application was only significantly raised when there was a *benzirigu* in the house. On the basis of the evidence presented in section 6.3 it is reasonable to suggest that this is not because *benzirigu* ownership is the only economic characteristic of farmers that raises their ability to afford fertiliser, but because few in the sample had reached the threshold levels of wealth at which these relationships become statistically apparent.

Some factors that confound the controlled nature of these comparisons should be noted. Individual situations vary: in particular, the amounts of compost farmers apply depend to some extent on personal non-structural factors as well as wealth. All farmers had different ideas about appropriate application rates, regardless of their wealth. The landlords' ownership of *sanbanni* farms also affects the relationship between wealth and application of one or two fertilisers: although *sanbanni* farms belong to the richest household members, they often receive no fertiliser due to their relatively high fertility. When landlords are removed from the analysis, 47 cases were left, and of the relationships shown in table 6.14, only one remains: only those farmers with bicycles were more likely to apply two fertilisers ($p<0.01$).

These results show that some richer farmers are able to carry out some aspects of recommended fertilisation practice, which may lead in turn to higher yields. However, as the majority of the sample did not have enough capital to fully implement recommended fertiliser application procedure, it is most useful to analyse the relationship between fertiliser application and capital within the context of a combined strategy.

6.6 Role of compost within wider fertilisation strategies

Chapter five focused very narrowly on the capital requirements of a particular aspect of organic fertilisation, compost carriage. Thus far this chapter has demonstrated the relative agronomic effects of compost and fertiliser and begun to consider the capital requirements of each. This can now be placed into a broader context by describing farmers' holistic fertilisation strategies and the capital requirements of the individual techniques they comprise. Statements can then be made about the most viable as well as the most effective strategies.

When farmers described their farm histories in the first round of interviews they all identified patches of more and less fertile soil. Farmers were rarely able to explain variation between these patches, ascribing it to soil variability. However, they did not associate this with soil type, which they separated into the four broad categories shown in table 6.16.

Table 6.16 Dagbanli soil type names.

Dagbanli name	**English translation**
Bihigo	Sand
Bolinga	Clay
Chichaly	Gravel/stony
Zoburugu	Hardpan

When soil fertility was explained it was ascribed to past management practices - namely manuring, kraaling, legume rotation, fallowing, ridging or vegetable plots. As is typical of smallholders, farmers did not distinguish finely between fertility and productivity, and many mentioned the effects of water flow and stagnation upon productivity in conversations about fertility. Patches of differing fertility and productivity made various combinations of SFM techniques appropriate for individual parcels of land and farmers.

Figure 6.6 displays the proportion of farmers using each of those various practices. Weeding and use of herbicide may not strictly be considered SFM techniques. However farmers who voluntarily gave these as answers to the question 'what have you done this year to keep the soil fertile?' explained that they did so because weeding and herbicide application reduced competition and made nutrients more available to crops. These responses reflect their concerns with productivity over fertility and are therefore preserved in the results. In the case of weeding it is certain that all farmers weeded their crop. The 17% who mentioned it spontaneously as an SFM technique are also represented in figure 6.6 to give an idea of their perception of the meaning of soil fertility. Ridging was also considered an SFM strategy by some farmers, who explained that it gathered nutrient-rich topsoil and made it more available to crops planted into it. Ridging for maize is presented in the results, as vegetables are always ridged yet are not the focus of this study.

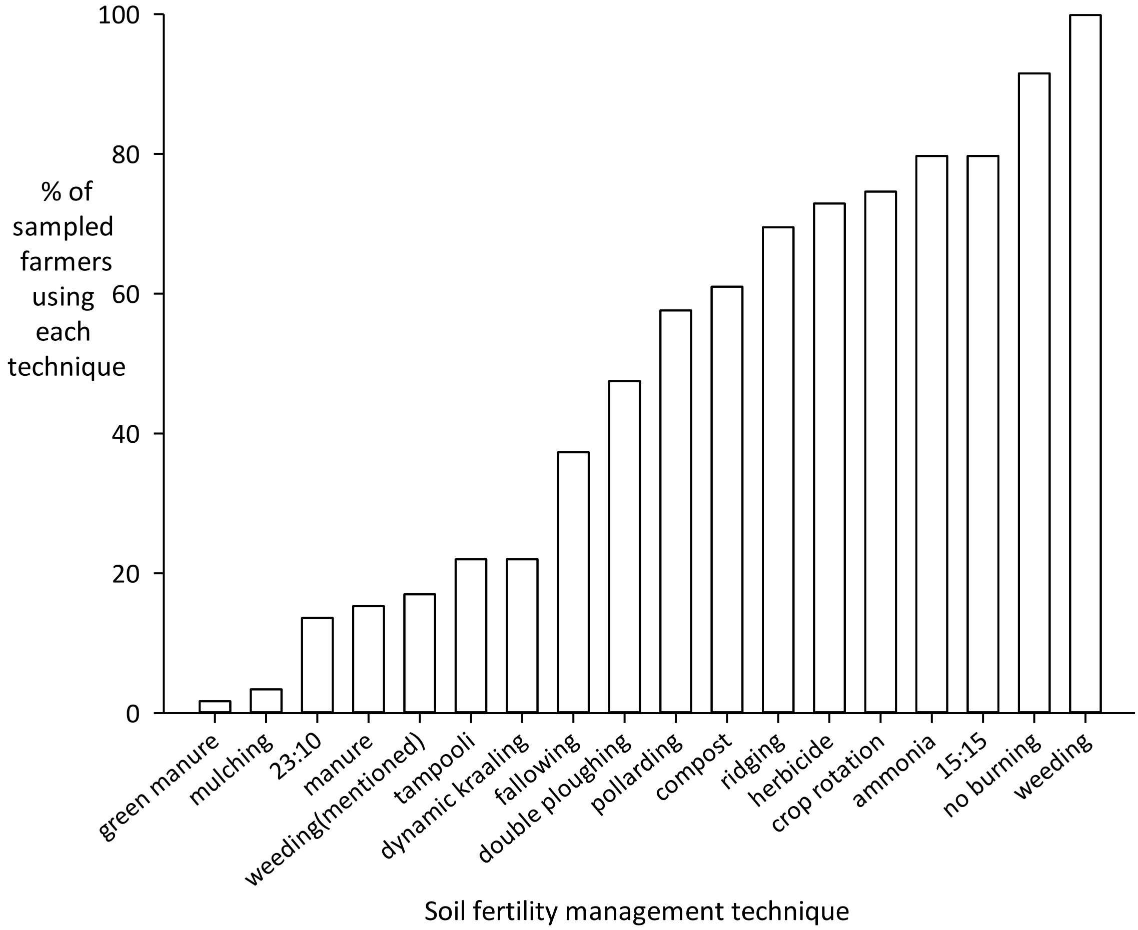

Figure 6.6 Percentage of the 60 farmers sampled who had used each soil fertility management technique.

Care should be taken when using figure 6.6 to compare the proportion of farmers using organic matter with the proportion using inorganic fertiliser, or to extrapolate the trends to the wider population. As many farmers used compound as well as ammonia fertiliser the total percentage of farmers using any fertiliser at all was 96.6%, whereas as study participants self-selected on the basis of their compost use, 100% of the sample added organic matter in the form of either compost, manure or refuse into the soil. The proportion of the general population would be much lower. Data from the pilot project preceding this study indicated that in any village it may be between 28.1% and 99.7% (Bellwood-Howard 2009).

Farmers also applied more than one sort of organic matter to the soil, hence their disaggregation in figure 6.6. The primary example was the propensity of the farmers in Zaazi in particular to use household refuse or *'tampooli'*. Their reasons for doing so can all be grouped as direct or labour-induced unavailability of higher quality manure and compost. At least five farmers gathered cow manure from the Fulani kraal slightly outside the village where the majority of their cattle were kept. However, the distance - about 1 kilometre, uphill - meant that farmers like the elderly Abrahaman Dohina found this a difficult task. Duado Alhassan Mohamed also considered that the manure was a community resource so one person could not take too much of it. Nevertheless, it was still a more popular option than making one's own compost. Few farmers in Zaazi intentionally made compost in pits or piles. Zaazi is situated near a reservoir, so in the dry season farmers are able to grow vegetables, which means there is less labour available for making compost. Two farmers explicitly invoked this reason in their second interviews.

This use of multiple sources of similar fertilisers illustrates farmers' strategy of employing a range of SFM techniques in order to draw on the most appropriate, depending on the type and amount of capital available to them at any time: the minimum number of techniques any one farmer claimed to have used was five.

Farmers' choice of strategies reflects a balance between what they are able to do and what they perceive as most effective. To identify the latter, they ranked the SFM practices they felt were first, second and third most successful at maintaining soil fertility. Scores were added and divided by number of farmers ranking them, making three the maximum possible weighted score. Figure 6.7 shows the weighted scores of each practice. The three inorganic (15:15, 23:10 and ammonia) and three organic fertilisers (compost, manure and refuse) have been grouped and presented as just two treatments, to facilitate the comparison between organic and inorganic amendments that is the main focus of this study.

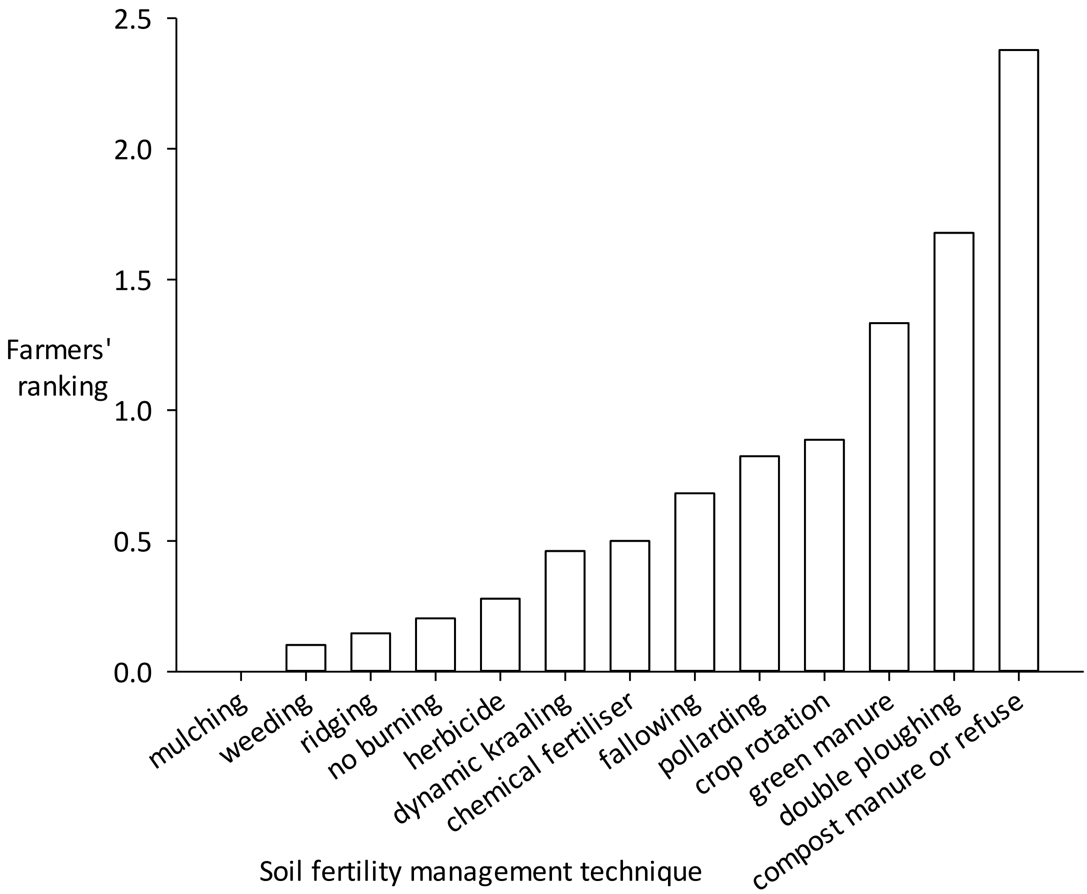

Figure 6.7 Farmers' rankings of their SFM techniques.

Farmers ranked organic applications as the best strategy for maintaining fertile soil, followed by double ploughing. The appearance of green manuring as the third most popular technique reflects more its reputation than its practical importance in the Dagomba farming system: only two farmers in the sample knew of this technique, but one of them ranked it as the most effective, thus raising its weighted score. It is possible that most people named compost as their preferred soil fertilisation technique in an effort to match what they perceived as the researcher's opinion. However, the five most popular practices involve incorporating OM into the soil (the benefit of crop rotation most commonly cited in interviews was the addition of leaves from vegetables and legumes into the topsoil). This is probably an expression of the farmers' knowledge that there is a need for OM as well as nutrients in the soil to improve non-nutrient properties such as soil texture that are difficult to quantify, giving weight to the idea that the positioning of OM incorporation at the top of the ranking scale reflects farmers' genuine opinions. These reflect the finding of section

6.3 that even applying inorganic nutrients at the recommended levels and on time were not related to higher yields.

This explanation illustrates another reason why Dagomba farmers use a range of SFM methods: as well as the differing capital circumstances that constrain or facilitate their use, each has different physical and agronomic advantages and disadvantages and performs different functions in the soil. These properties imply strong sustainability and also lead to certain technical synergies between them.

6.8 Substitution and synergy of methods

Before examining some examples of such synergies, it is instructive to detail some occasions when participant farmers made substitutions between different techniques within their overall SFM strategies, as a result of changing capital availabilities.

One example comes from Alhassan Sumani who switched to organic matter incorporation when he could not get enough money to buy groundnut seeds to practice crop rotation. Habiba Twahidu, in the same situation, was forced to fallow the field she had intended to sow with groundnuts. A lack of human capital for weeding can be circumvented if the farmer has the financial capital to purchase group *kparaba* labour, herbicide or even extra fertiliser. An interesting example is Suali Kpaliyoggo who felt too tired during Ramadan to weed both his landlord father's field and his own. Foregoing the former was not an option, so, despite having applied 23:10 fertiliser to his maize he returned to sidedress ammonia so the maize plants could outcompete weeds. Suali had invested much labour into his tomato farm early in the season, so was able to use the cash from selling the early fruits to purchase ammonia. These examples illustrate that the most important benefit of access to a range of capitals is that it facilitates choice between, and substitution of, fertilisation techniques.

Substitution of one technique for another is not a surprising tactic. More interestingly, synergy occurs between fertilisation methods, as it did for transport strategies. As well as the importance of having capital to switch practices, it may be helpful in more than an additive sense to combine them. The orthodoxy that combined application or ISFM is the best strategy refers not just to organic and inorganic amendments but to combinations of all possible SFM techniques (Palm *et al.* 1997). Reflecting this, five farmers described how double ploughing was more effective when combined with herbicide application before ploughing. This provided additional dead plant material that would rot faster having been chopped, mixed and aerated in the ploughed topsoil. Crucially, as the weeds had been killed by the herbicide they could not then regrow and compete with crops for those nutrients.

Application of any form of OM as well as macronutrients acts to improve soil structure and therefore the qualities like water retention held responsible for the better performance of composted than fertilised plots in section 6.3 and 6.5. Fertiliser efficiency is also improved as inorganic nutrients may be retained on organic surfaces and edge sites (Nyamangara *et al.* 2003). Thus, many farmers applied fertiliser to fields that had already received compost or OM from techniques like cutting leaves of trees.

Application of ammonia to plants fertilised with compost is recommended by MOFA (Aflakpui *et al.* 2005) and is probably one of the lowest risk and most cost effective synergistic strategies. MOFA AEOs explained in interview that use of compost incorporates OM, macro- and micronutrients into the soil on time and ammonia requires less financial capital later in the season than compound. Ammonium ions held to organic molecules are less likely to leach away or nitrify. Similarly, ridging combined with organic matter application concentrates nutrients around the base of plants more than if they are sown into ploughed land, and application of organic matter makes more fertile, friable ridges than those comprising topsoil alone.

These examples of substitution and synergy make it clear that, despite farmers' preference for organic amendments displayed in figure 6.7, access to a wide variety of capitals, and therefore the ability to select from and combine many SFM techniques, is more important than having the physical and financial capital necessary to apply high levels of compost alone. This echoes the findings of Chapter five that access to multiple modes of transport facilitates the most effective transport strategy. If use of multiple techniques is necessary it is useful to determine exactly which capitals each requires as they are differentially appropriate between settings.

6.9 Capital requirements of favoured strategies

In order to elucidate the specific capital requirements of each SFM strategy farmers identified as important, they were asked whether they needed anything to enable them to carry it out and if so, what. Here their answers to this question are considered in the context of the literature. There were some major methodological considerations attached to this question: it should be borne in mind in particular that a farmer's reference to money often reflects more their perception of the role of the researcher than their opinion of the capital requirements of the SFM technique. Nevertheless, the data is revealing and is presented as farmers stated it, as it is impossible to judge how 'true' their responses are.

The data for most strategies farmers rated as effective will be shown in figured 6.8-6.19, leaving fertiliser and compost until last as they are examined in slightly more detail. Some very similar responses have been grouped e.g. all those relating to collection of materials for composting. However, it is useful to leave some of the data in the original format as this gives insight into the farmers' suggested strategies for obtaining the necessary capital (see, for example, figure 6.15). As the data is summarised the implications in terms of the types and sources of capital required is considered, allowing contemplation of the extent to which different types of goods and capitals are involved in successful SFM. This will lead in turn to consideration of the most appropriate systems of capital use and thus to which of the capitalist, participatory, structural and traditional development paradigms they best fit. The section will consider fallowing, weeding, ridging, crop rotation, mixed cropping, green manuring, pollarding, double ploughing and dynamic kraaling before turning to inorganic and organic fertiliser application.

6.9.1 Fallowing

Under fallow conditions, SOM builds up from roots and microorganisms, increasing first rapidly then more slowly, although the function of this curve varies between biomes (Nye and Greenland 1960; Irvine and Ahn 1970; Manlay *et al.* 2002). These processes do occur in the rhizosphere of cropped fields, but in fallowed sites the above-ground portion of the plant is also seasonally incorporated into the topsoil as it senesces and biodegrades. Improved fallow systems, similar to green manures, can regenerate SOM more quickly than natural vegetation (Kaonga and Coleman 2008).

Fallowing is the only SFM strategy that primarily requires natural capital in abundance, and thus demonstrates the strongest sustainability. These days, however, it interacts with other forms of capital far more than in former times when it was the dominant method of SFM. Fallowing does still occur and 18% of farmers considered themselves able to practice it. It is not always chosen voluntarily as an SFM strategy: one farmer with few children and little money said he wanted to plough his whole field but was forced to fallow as he lacked cash for the tractor or bullocks. Nevertheless, although it has not yet been exhausted, natural capital in the form of land is declining. Thirty-four percent of farmers stated spontaneously that there was insufficient land available for them to leave any fallow. This indicates that land is indeed in short supply in this peri-urban zone. Figure 6.8 supports this. It shows farmers' responses when they were asked what they needed to practice fallowing.

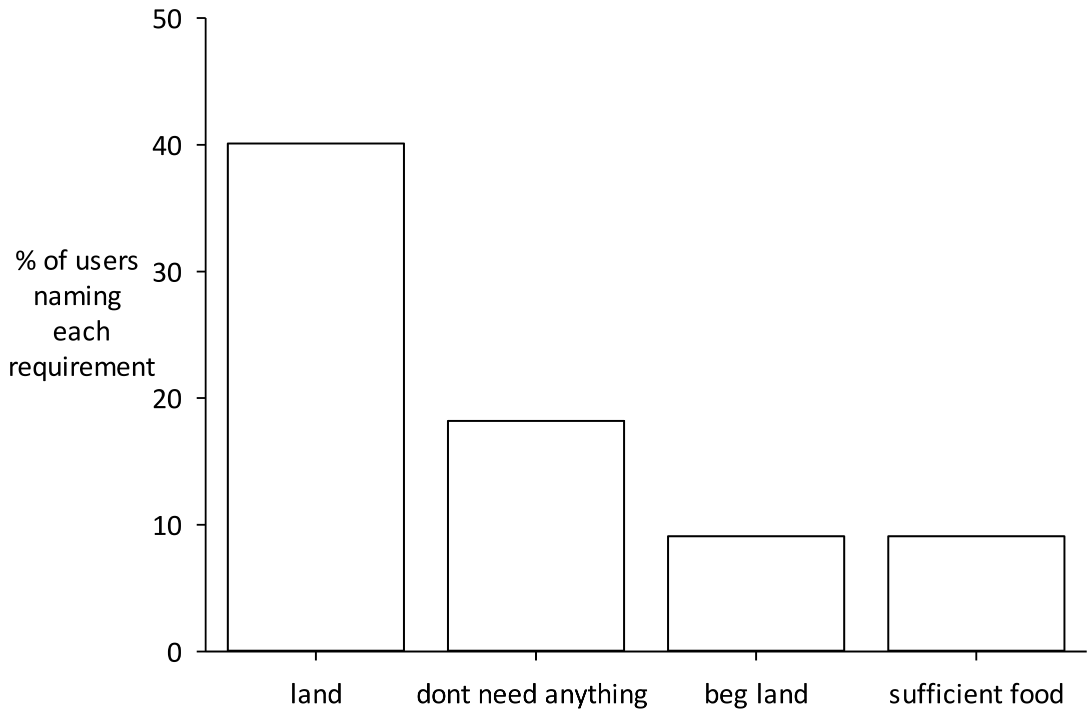

Figure 6.8 Perception of the 22 farmers using fallowing of its resource requirements.

Farmers now replace the natural capital necessary to fallow with alternative types of capital, and one strategy is to use social capital and borrow land to farm on, either in order to fallow one's own or because this is fully sown and more is needed. The third column in figure 6.8 represents this practice and was also mentioned by eight farmers in in-depth interviews. Five farmers, all from Zaazi, also describe coming under pressure to loan land they intended to fallow for soil fertility purposes. The influence of the traditional system of kinship exchange and expectations of reciprocity is clear here**.** The majority of land in this peri-urban area of Western Dagbon belongs to individuals, inherited through their patrilineage. An individual's father's land endowment and ability to fallow therefore translates into what could be described as natural capital and the ability to fallow is related in part to accumulated capital. However this private land ownership is associated not only with the capitalist system of private property but also occurs in the context of traditional family usufruct relationships. The ability to 'borrow' land that is owned by an individual means that, as with *benzirra* and animal ownership, the traditional system can allow access to property owned by individuals. Relatives, in particular, may have reasonable expectations of being able to borrow land from kin. It is important to clarify that although the land is held under traditional laws and a certain amount of borrowing and sharing does occur within the family this is very far from 'communal' ownership or an open access common property regime, as some colonial authorities perceived it to be when such a narrative facilitated its alienation (Colson 1971). Although access to and inheritance of land occurs through a traditional system that emphasises mutual support, the benefit derived from its use accrues to the individual user or owner and their immediate household. Those with more financial capital can very occasionally buy land, but social capital is also a type of purchasing power in this respect as land can be as easily 'begged' or 'borrowed' in a traditional exchange as it can be rented.

In fact, in peri-urban Dagbon, land is rarely purchased with money. However there is another route through which individual's financial capital may facilitate fallowing. Slightly more people in Zaazi than in Ypilgu mentioned fallowing as a strategy they had practiced. This could be because income generated through market sales of intensive, high value irrigated vegetables allows landlords to purchase maize, relieving somewhat the pressure on their extensive subsistence maize farms: diversification and market integration in Zaazi thus reduces the acreage cropped and increases the availability of fallow slightly compared to Ypilgu.

Despite almost all the land around the study villages being individually owned, there are small areas of fallow that are communally owned and managed for special functions (e.g. cattle paths to water, woodlots, a taboo site of an ancient battle field), and it is understood that these should not be cultivated. Farmers know these areas of land to be more fertile: some whose farms bordered this land reported annually shifting their farm boundaries slightly to incorporate slices of fallow into their farms. Field analysis confirmed the higher fertility of these soils. Characterisation of two fallow soils and adjacent farmland was carried out using the tests described in Chapter four and Appendix 7. Results of these analyses showing fallows to have more favourable soil properties are displayed in table 6.17, and figure 6.9 shows the colour difference between soil taken from a fallow and an adjacent farmed plot.

Table 6.17 Comparison of fallow plots and adjacent farmland.

	Tambiegu fallow (taboo site)	**Adjacent farmland**
Dry soil colour	10YR4/6	10YR4/6
Wet soil colour	10YR3/2	10YR3/6
Structure	Moderate blocky, 10cm aggregates break into peds 2-5cm wide when crushed forcibly	Moderate blocky, 10cm aggregates break into peds 2-5cm wide when crushed gently
Texture	Loamy sand	Loamy sand
Description of slake test	Aggregates retain 100% structural integrity after 5 minutes immersion in rain water	Aggregates immediately lost all structural integrity and dispersed into sand particles upon immersion
Slake test	Class 6 – most stable	Class 1 – least stable
Topsoil profile	Top 3 cm has large loose aggregates up to 5cm across	Uniform compacted profile to 10cm
Root density in $100cm^2$ profile	81	80
Max. root thickness	>1mm	<1mm
Max. root branches	2	1
	Tierrigini fallow (stony, unfarmed land)	**Adjacent farmland**
Dry soil colour	7.5YR6/4	7.5YR7/4
Wet soil colour	7.5YR3/4	7.5YR5/4
Structure	Blocky aggregates break into peds 1-5 cm wide when disturbed	Blocky aggregates break into peds 1-5 cm wide when disturbed gently
Texture	Clay loam	Sandy loam
Quick slake test	Expanded within 30s. No change after 5 minutes	Expanded in 5s. Disintegrated at 30s. 20% disintegrated after 5 minutes.
Slake test	Class 6 – most stable	Class 6 – most stable
Topsoil profile	Uniform compacted profile to 10cm	Surface crust. Uniform compacted profile to 10cm
Root density in $100cm^2$ profile	162	33
Max. root thickness	>1mm	<1mm
Max. root branches	2	0

Figure 6.9 Soil samples from adjacent fallow and farmed sites.

The main difference between fallow and farmed soils was that soil aggregates were more stable in fallow plots. Darker soil colour indicates that this is probably a result of higher OM. Aggregation as a result of SOM incorporation or wet-dry thaw cycles is common in tropical climates, often masking the true clay sized soil particles in sand sized aggregates (Ahn 1979). Such stable aggregate structures result in more pore space and therefore easier root penetration and air flow to roots (Hati *et al.* 2006). Reductions in organic matter content, for example due to carbon oxidation from continual tillage, may then result in the more compacted and therefore less productive profile found in the farmland. This relates directly to the ascription of higher soil water retention in composted plots to higher SOM levels in section 6.4 and 6.5. As addition of organic amendments raises OM contents in soil (Willson *et al.* 2001; Mando *et al.* 2005) these results add to the evidence that higher soil water retention is a primary mechanism through which such amendments raise yields.

As it facilitates fallowing, potentially leading to improvements in soil character, it can be said that owning more land, whether through traditional means or capitalist purchase, does allow farmers to improve soil fertility.

6.9.2 Weeding

An activity not traditionally conceived of as an SFM technique, weeding reduces competition for nutrients and therefore can be considered to increase the relative fertility available to plants. Figure 6.10 reveals that this practice, which apparently relies on human capital, has a range of capital requirements.

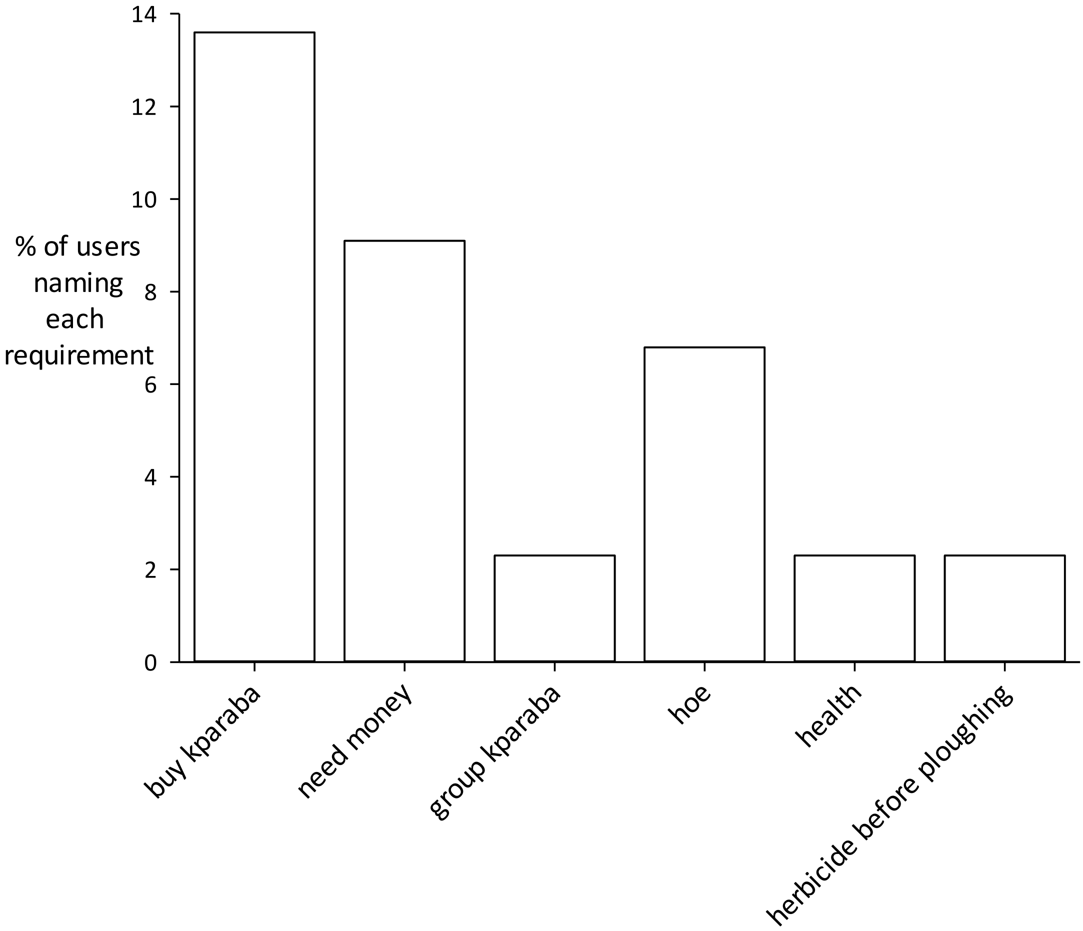

Figure 6.10 Perception of the 60 farmers who weeded of its resource requirements.

A farmer may rely on his own human capital, but is unlikely to be able to weed the whole area in time alone. Most thus turn to the use of human capital located in their households or communities and accessed through three major different institutions that represent three different paradigms.

Firstly, while family labour is more commonly used more for sowing, a senior farmer with much social capital may compel his junior household members to weed for him within the traditional system of household reproduction and obligation. Widening the scale at which his individual social capital may act, if he engages the services of the work party or *kparaba* he uses human capital held by other members of the community. If he pays them for their labour, he is entering the capitalist labour market. A related transaction occurs when villagers pay each other for weeding labour 'by day' in one-off arrangements. Here social bonding capital acts as an entry mechanism to the capital labour market. When farmers were asked about the resources necessary for weeding, their most common response was about needing cash for this type of transaction, although this result should be tempered by the caveat explained in Chapter four regarding the reasons why farmers were eager to emphasise the importance of individual financial capital to the researcher.

Another scenario which would not involve the researcher giving money to respondents is the group work party. Farmers who participate in reciprocal *kparaba* work on their peers' farms in return. This traditional arrangement is close to a participatory situation, because all members of the *kparaba* accept the terms of the agreement and enjoy the benefits of timely weeding on their farms. Also, group social bonding capital gives access to the individual human labour of each individual. However, as it exists within the traditional reciprocal system of household reproduction *kparaba* is not a fully participatory or communal solution: Maghimbi (1994) makes the point that after the *kparaba* has weeded the farmer's field the remainder of the tasks are his responsibility alone, and he and his household use the harvested maize.

Berry (1993) describes how these different systems exist alongside each other. Kinship is a permanent, indelible relationship within the traditional system, whereas less formal alliances may require constant reinforcement to keep them valid. Paid *kparaba* may therefore involve fewer obligations to attend. There are multiple distinctions within as well as between systems - Awanyo (2001) describes how husbands in Brong-Ahafo, Southern Ghana, must persuade their matrilineal clan to help them weed when their wives withhold their labour, showing the different layers of traditional labour arrangements that exist within what has been defined for the purpose of this study as a homogenous 'traditional sphere'. Participatory, capitalist and traditional solutions thus co-exist within the village and increasingly within the same task or group.

Figure 6.11 also illustrates that if herbicide is used an individual's financial capital and the market can be used in a totally different way by purchasing a product to replace the human capital used in weeding.

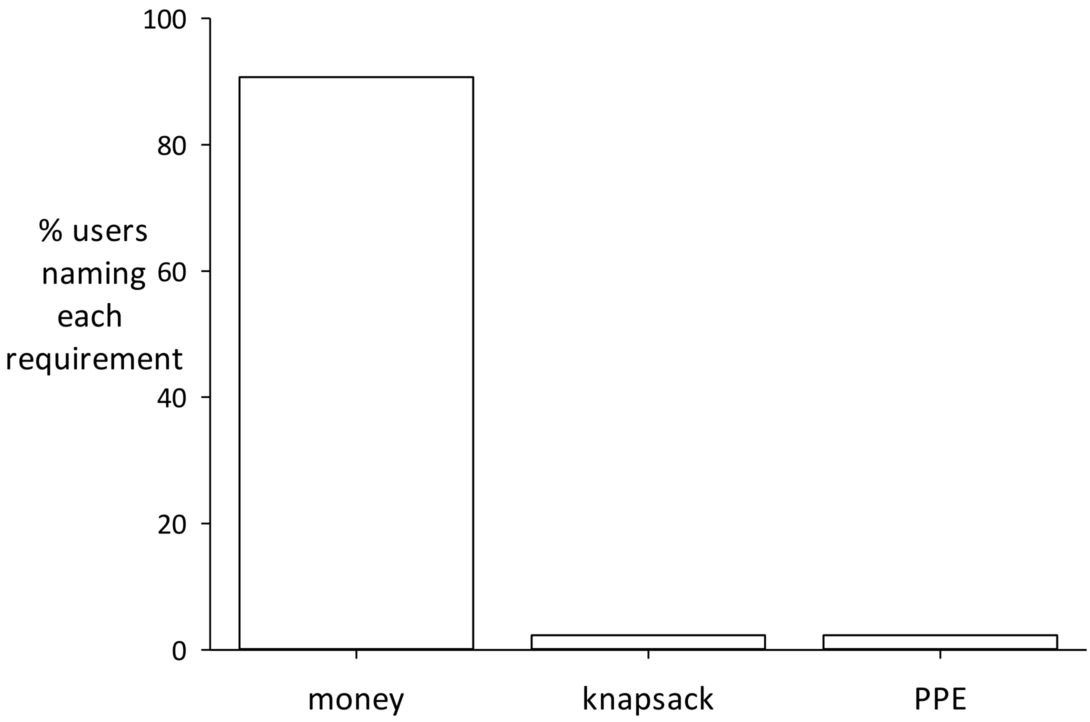

Figure 6.11 Perception of the 43 farmers using herbicide of its resource requirements.

6.9.3 Ridging

Another manual technique, ridging, as opposed to ploughing, concentrates topsoil around the base of the plants and thus provides a more nutrient rich environment. An additional benefit of ridging is that moisture is conserved more effectively than on a flat field. Figure 6.12 shows that this technique, like manual weeding, relies more on human capital than anything else. *Kparaba* is rarely employed for ridging, so a farmer relies mostly on his own and his household's human capital to perform this task.

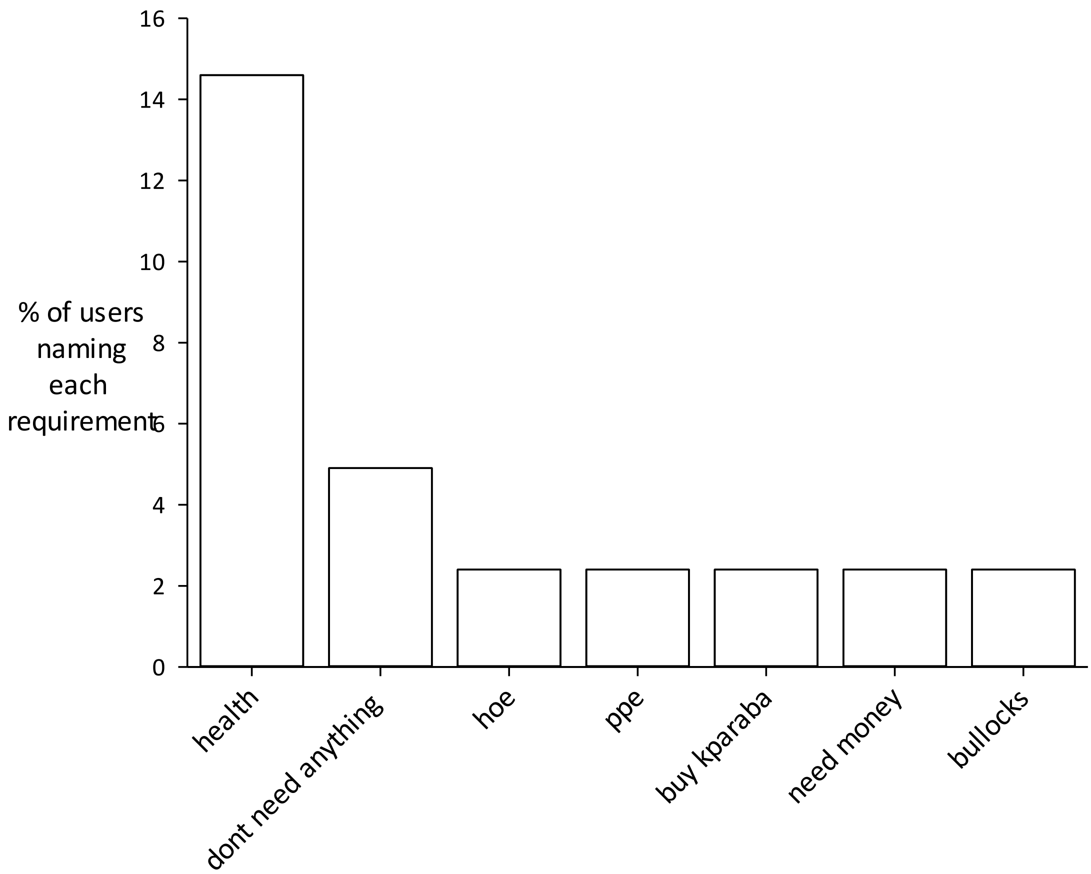

Figure 6.12 Perception of the 41 farmers who ridged of its resource requirements.

6.9.4 Crop rotation

Rotation of legumes and cereals fixes nitrogen into the soil in alternate years. In Dagbon it is generally practiced on fields at a medium distance from the village. As related in Chapter four, untethered livestock would destroy legumes planted around the village due to their earlier planting date, preventing crop rotation on *sanbanni* maize farms. In the bush farms very far from the house, legumes, predominantly groundnuts, dominate every year, due to farmers' inability to transport fertilisers to these fields and the relative ease of transporting groundnuts home.

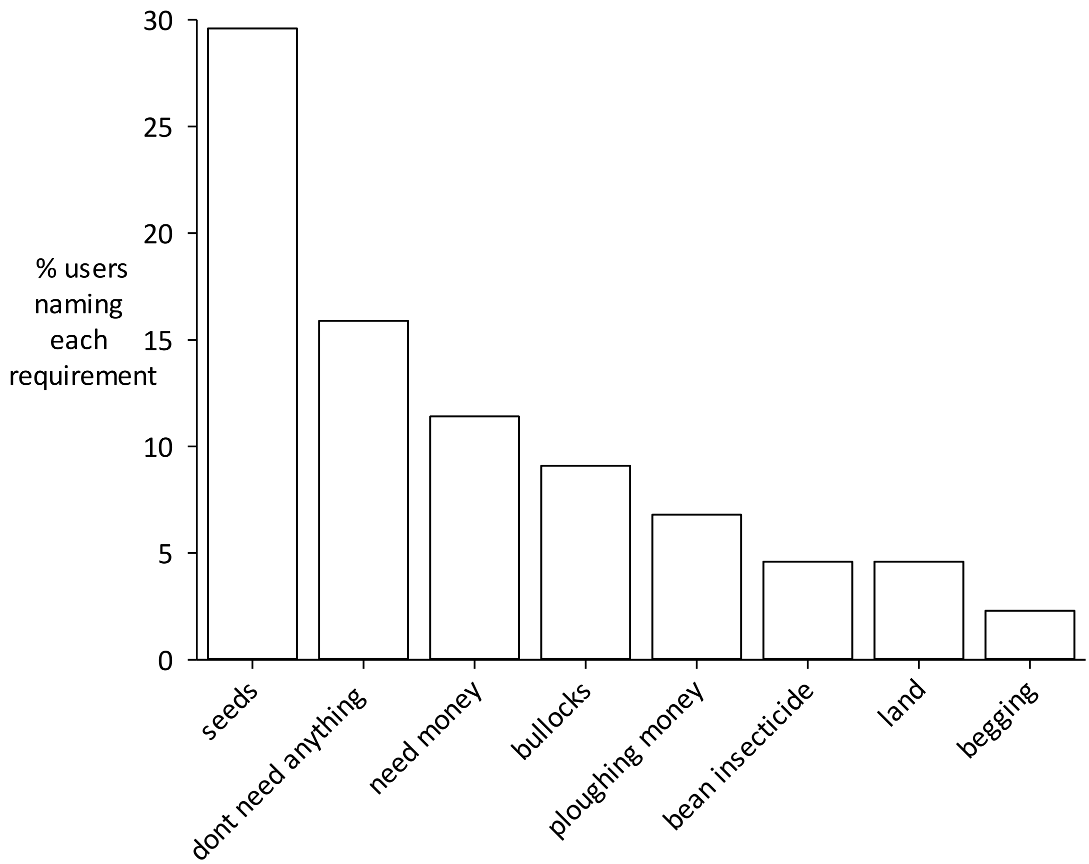

Figure 6.13 Perception of the 44 farmers using crop rotation of its resource requirements.

Figure 6.13 illustrates two interesting points. Firstly beans, especially cowpea, are very susceptible to insect attack and farmers therefore perceive purchase of insecticide to be essential: this is one reason why maize-groundnut rotations are more common. The purchase of insecticide means crop rotation is tied to the market and the capitalist system of production, as does the use of market legumes as nitrogen fixers. As groundnuts and beans are cash crops, individuals may need to sell them immediately after harvest and then invest cash for seed next year. Crop rotation is therefore a more risky SFM strategy than it may seem.

Secondly, some farmers mentioned ‘begging’ or borrowing seed – an element of the ‘traditional’ mode of production found to be so important in Chapter five. This is the only way in which capital besides that belonging to the individual farm owner is involved in crop rotation, and even begging for seed requires the farm owner’s social capital for the exchange. As poorer people usually sell most of their groundnuts at harvest they have to ‘beg’ for more next sowing season. This transaction between two individuals involves two individuals’ social capital within the traditional local market that does not necessarily involve cash. Again, the capitalist and traditional systems are associated.

6.9.5 Mixed cropping

Rotation of monocrops is less common than mixed cropping which is widely practised in Dagbon (Kipo 1997). The term describes a range of practices involving varying degrees of simultaneous cropping intended to increase returns to land or reduce risk: sowing multiple species in one place guards against total crop failure on a limited land area in the event of drought or pest damage. Mixed cropping comprises a valuable set of agricultural management techniques. However, as it addresses issues other than soil fertility alone and is not an amendment to the soil it is not one of the main foci of this study and will be given shallower consideration here. Crops with different rooting depths and growth habits use different stores of nutrients within the soil profile as well as having different light and space requirements. Species planted at overlapping periods may use nutrient flows released at different times as well as smoothing the labour profile (Swindell 1985). Legumes may fix nitrogen that cereals planted later in the season take up (Richards 1986), similar to the principle employed by relayed market legume green manuring. Common Dagomba crop mixtures are detailed in figure 6.14.

Root crop-based	Cereal-based		Legume-based
Yam/Cassava and Millet	Maize and Millet	Maize, Millet and Groundnut	Groundnut and Beans
Yam/Cassava and Maize	Maize and Groundnut	Millet and Groundnut	
Yam/Cassava, Maize and Millet	Maize and Cowpea	Millet and Beans	
Yam/Cassava, Maize and Beans	Maize and Beans		
Yam/ Cassava and Beans			

Figure 6.14 Common Dagomba crop mixtures.

Agroforestry mixes annuals and perennials. It therefore provides green manure or residues for incorporation as well as conserving soil cover. This technique is rare in Dagbon, as the dominant economic trees either have waxy, recalcitrant leaves (like shea *(Butyrospermum parkii*), and mango *(Mangifera indica)*) or are difficult to establish in plantations (like shea and dawa dawa (*Parkia biglobosa))* (Chalfin 1996). Leucaena *(Leucaena leucocephala)* and moringa *(Moringa oleifera*), which can grow in plantation, are known, but not currently commonly used by smallholders. Moringa also has small, soft easily degradable leaves, but as they are sold as soup and medicine they are also too valuable to use for soil fertility purposes. Teak (*Tectona grandis*) and neem (*Azadirachta indica*) are more common. The former may be observed in small plantations of up to 20m^2, its leaf litter forming under closed canopy for up to 10 years. However the 10 years minimum required for this investment to reach maturity necessitates an initial amount of human capital for the same reasons as green manures. Agroforestry is thus at present an underused technique.

6.9.6 Green manures and crop residue incorporation

Only two farmers were aware of green manuring and neither had practised it recently, despite one considering it a useful technique. Growing and incorporating green manures into the soil may seem to be less of a market embedded practice, but the scarcity of capital, time and the requisite land area (Bationo and Mokwunye 1991b; Quifiones *et al.* 1997; Breman *et al.* 2001; Bunch 2003) means this practice is only profitable if an element of market integration is incorporated.

Green manuring rarely improves yields enough to be used as a sole SFM technique, but when considered as one of a possible range of methods there are three categories of green manures from which farmers could choose. Firstly, non-market rainy season species like the velvet bean *Mucuna pruriens* that would be grown alone in a field for a season are highly unlikely to be adopted as they remove the land from a profitable purpose for a season - especially as farmers in the monomodal savanna climate have only one season a year in which to grow food. Secondly, there are some intercropped green manures that can be relayed with market or subsistence foods. *Crotalaria* spp. provide a particularly useful example as they can be broadcast between maize and, critically, can flourish during the dry season ready for incorporation the following ploughing season. The third type of green manure overlaps with this - if the residue of market crops, especially legumes like groundnuts and soya beans, can be grown and the residue re-incorporated, they may not make a loss in the year of application. Occasionally these can also be relayed or more commonly intercropped with cereals. Such market legumes are the only forms of green manures likely to be adopted. Their profitability depends on market prices (Bunch 2003; Franke *et al.* 2004; Adjei-Nsiah *et al.* 2008) and their cultivation is primarily for sale, not reincorporation for soil fertility amelioration. The seeds of legumes are also more accessible, through peers, self storage or the local market, than specialist green manures which would be obtained from extension personnel.

Cereal crop residue can also be incorporated, although there is competition for the stover between the functions of building, fodder, and craft (de Ridder and van Keulen 1990; Bationo and Mokwunye 1991b; Quifiones *et al.* 1997). In Dagbon, cereal stems are used for mat making, thatching and fencing and are therefore rarely used to enhance soil fertility because, like *Mucuna* and *Crotolaria,* this does not produce an immediate financial gain. Bationo and Mokwunye (1991b) see a role for fertiliser in producing larger crops and thus more residue and root volume, but it has been considered in section 3.5 that annual application of the required quantity of inorganic input is unlikely in this context.

Even after a green manure has been produced, there are labour costs involved for spreading the residues prior to reincorporation, which could translate into cash costs if farmers decide to use traction.

Even a profitable crop cannot be adopted if it is agroecologically incompatible, and in the moisture-limited savanna timing is paramount. Although soyabean was a profitable green manure when relayed with maize in Northern Nigeria (Franke *et al.* 2004), its long growth period meant that the subsequent maize crop was drought-stressed towards maturation. Adjei-Nsiah *et al*. (2008) made a similar observation for the 'legon prolific' groundnut variety in rotation with maize, stressing that appropriate agroecological and economic species and varieties of green manure must be used. However Ouédraogo *et al*. (2001) identify a role for compost in alleviating such constraints by improving the water retention capacity of soil when used in combination with green manure, one of the beneficial interactions of ISFM to be discussed shortly.

In arid or humid tropical areas where soil can lie bare during rainfall, green manures may act as a cover crop or living mulch to reduce erosion (Bationo and Mokwunye 1991b). In Dagbon erosion occurs as a result of harmattan winds in the dry season, and although Bunch (2003) states that dry season cover can guard against this, only irrigated crops can grow in Dagbon when no rain falls. Normal crop cover in the wet season will guard against rainsplash, and therefore any additional green manure crop will have a negligible effect on erosion over that which would be provided by crops.

Those with larger personal stocks of human capital may be more able to afford the labour investments entailed in growing green manures, and those with more land could possibly sacrifice a field's maize yield. The incorporation of green manures thus works best when integrated into the capitalist market economy. Obtaining crop residues can entail an element of social capital, for example if begging for stover from another, implying the traditional economy, but financial capital is often involved, for example when purchasing wastes like rice husks (Franke *et al.* 2004). This means that, as with the use of market legume green manures, it can be part of an exchange system inaccessible to the poorest.

6.9.7 Pollarding

Pollarding is another form of green manuring where branches are cut, laid on the ground and the leaves allowed to drop before the timber is used for building and firewood. The practice is instigated most commonly by the need for wood, sometimes by the observation that trees are overshadowing crops, or occasionally by the desire to enrich the soil. The interaction between different reasons for this practice shows that SFM is tied to other livelihood activities, each with their own capital prompts and implications.

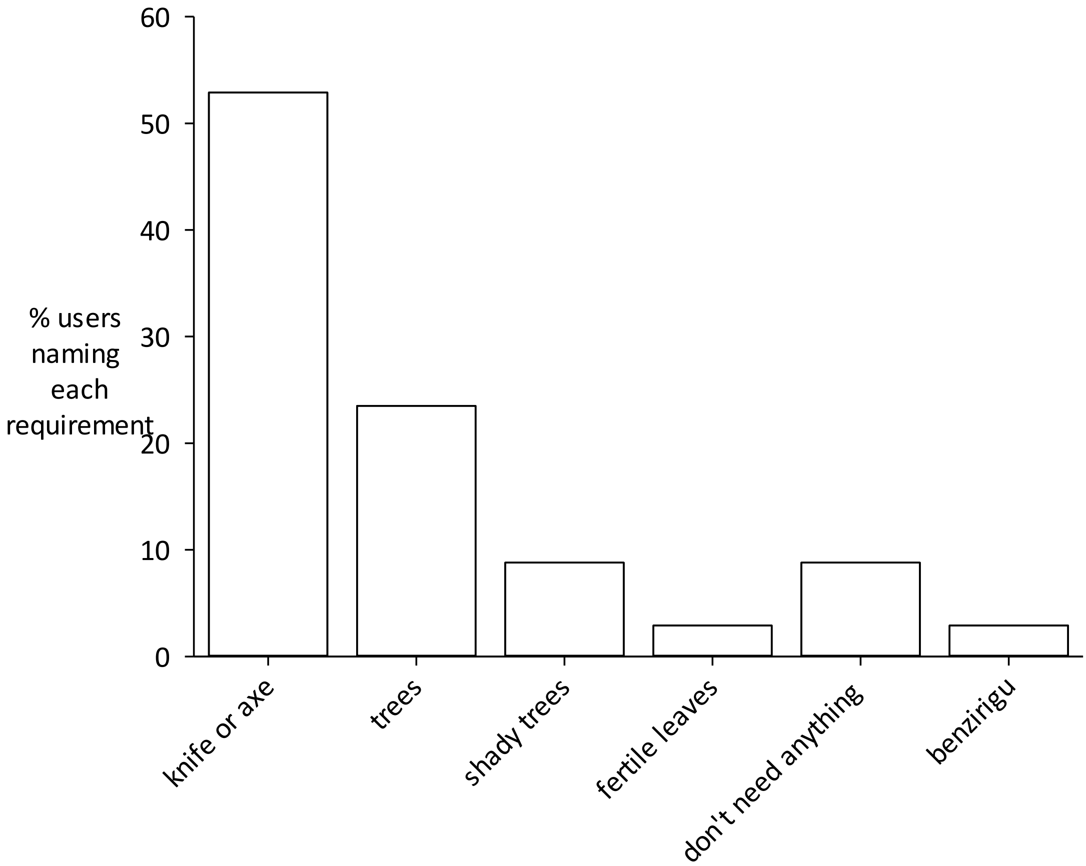

Figure 6.15 Perception of the 34 farmers using pollarding of its resource requirements.

Pollarding ostensibly does not involve market style transactions - figure 6.15 shows that the financial and physical capital demands are low. Little financial capital (2-5Ghc) is necessary to purchase the cutlass that most farmers named as necessary to pollard trees and a small amount of social capital could be necessary to borrow it from a household member. However, the fact that the second most common response was that farmers need trees to be able to pollard hints that the availability of natural capital may be decreasing, raising issues about the sustainability of the practice. Political ecologists have tackled the issue of deforestation in the West African savanna. As described in Chapter three, Fairhead and Leach (1995) and Basset and Zueli (2000) refuted a colonially inspired narrative of deforestation, using historical written accounts, interviews with contemporary farmers and satellite photograph data. In their studies in the forest-savanna transition zones of Guinea and Cote d'Ivoire afforestation occurs as farmers plant trees around villages and cattle herbivory reduces competition from grasses. Yet the data in 21st century Dagbon shows that here, a change in tree density and more importantly, species diversity, is affecting the ability to pollard, as well as perform other livelihood activities.

These two narratives are probably differentially relevant to different sites. Indeed, in peri-urban Dagbon the role of trees is not clear cut, as they are beneficial in some senses but disadvantageous to agriculture in others. Although the tap roots of some may pump nutrients up from deeper in the soil profile (Vetaas 1992), this beneficial effect must be weighed up against their shading effects on crops, especially rice. As political ecologists point out, the value of trees in the landscape depends on the definition of what *is* beneficial, and thus the relative value of natural and financial capital.

Deforestation was not a major focus of this work, so outside the farmers' interviews, little data was collected on it. But it is relevant: even compared to taboo and communal lands in the study sites and roadside sites 30km outside Tamale, the peri-urban farm landscape around Zaazi and Ypilgu is disproportionately dominated by small, young individuals of the economically useful mango, shea and dawa dawa species (Drechsel and Reck 1997). It was described earlier how the waxy leaves of the first two do not rot well, but how, more importantly, as these trees have valuable products, pollarding them for soil fertility purposes is not cost effective. Interviews performed by the authors above record farmers' narratives of afforestation to more utilitarian species compositions as they encounter similar resource use competition in semi-wooded landscapes. Two Dagomba farmers interviewed in the study area, on the other hand, mentioned that pollarding was now only possible for them every three years or so when trees overshadowed crops, and outside the formal interviews another explained how 'now you can see to Yirikpani (the adjacent village to Ypilgu) whereas before it was all bush', implying that although a similar change in species composition to more useful species has occurred, it has hitherto been more part of a process of deforestation of less widely used species than afforestation with more economically advantageous ones. As the density of indigenous trees declines and economically useful ones come to dominate the landscape, questions about their ownership begin to arise. Women do have usufruct of shea and firewood trees on their husbands' farms. As the softer, more readily degradable leaves of cassia (*Cassia siamea)*, neem and leucaena are more appropriate for green manuring than those of these traditional economic trees some farmers are now beginning to plant them. This is occasionally encouraged by NGOs and the Ministry of Forestry, who, for example, gave out free seeds to encourage farmers to start nursing cassia at Zaazi. Neem has been planted around villages for building and firewood, although, as for moringa, this location does mean that it is less appropriate for pollarding for SFM purposes. The conflict between the needs of farmers for space in which to grow their crops, the nutrient values of some varieties of tree and the economic benefits of trees with valuable products means that deforestation is still a concern. But increasingly, tree planting means that the types of concerns highlighted by political ecologists will become more relevant as a market of private ownership of scarce, valuable, useful trees and their products develops further. This will apply to pollarding as one of many competing uses of trees. Such issues of ownership of natural capital like trees again link the capitalist and traditional systems. It is conceivable that a capitalist type system of tree ownership could become more dominant in future years as trees become more excludable.

6.9.8 Double ploughing

Double ploughing is the commonest form of green manuring in Dagbon. An unburnt field is ploughed using bullocks to incorporate grass into the topsoil, then reploughed and sown between two weeks and two months later. A tractor would cover the overturned grass with 30cm of sandy soil, whereas bullocks plough only 15cm deep. Bullocks are therefore preferred by many for double ploughing, especially by those who own them, who then avoid paying cash to hire a tractor. However, figure 6.16 illustrates that as the majority of farmers do not own cattle the overriding resource needed to facilitate double ploughing is an individual farm owner's financial capital to hire traction. This is especially constraining at the ploughing time of year when capital reserves from the previous year's harvest are at their lowest.

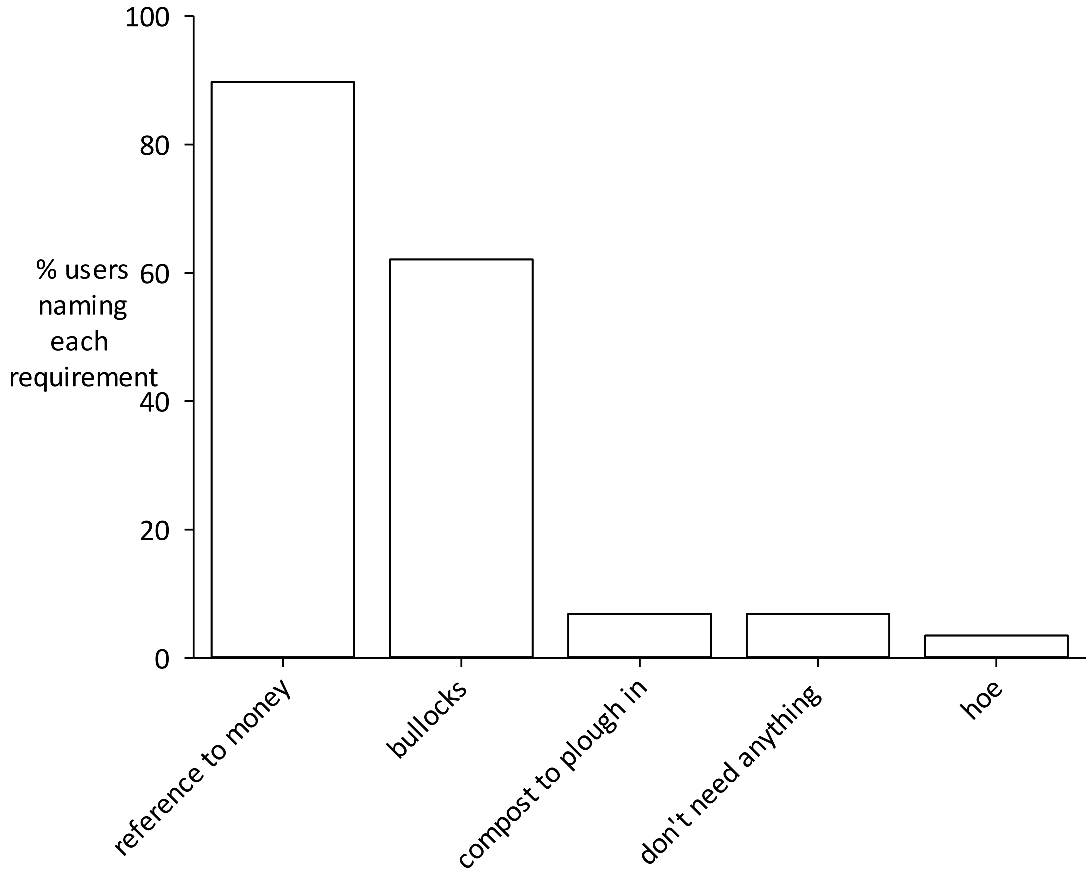

Figure 6.16 Perception of the 28 farmers using double ploughing of its resource requirements.

Even bullock owners have to consider the relative profitability of using their animals' and sons' labour for double ploughing their own fields or for ploughing their neighbours' field for cash. Section 5.6 found that social capital can sometimes, but not always, substitute for access to household bullocks for carriage of compost. Similarly, a cattle owner may hire the animals to customers for groundnut ploughing between April and July, meaning their availability to household members wishing to use them for maize double ploughing will then depend upon the balance of social capital, power and individual relationships within each household - the 'non-structural' factors Bloch (1973) identified as difficult to model. Participant observation and the interviews conducted in

2011 suggested that bullocks are generally available to household members senior to the owner, which includes the landlord. Bullock use therefore involves individuals either making cash payments or using their social capital within the traditional household system.

The blurry boundary between capitalist markets and the exchanges of traditional reciprocity, seen so many times in Chapter five in connection with *benzirra,* is encountered in most situations relating to ownership of the semi-subtractable asset of cattle. Livestock ownership is associated with wealth in terms of other assets as well as cash (Dercon 1998; Morris *et al.* 1999; Dossa *et al.* 2011) and is thus often used, as it was here, a part of a wealth proxy (Grace 2004; Kristjanson *et al.* 2005). In Dagbon, due to the traditional system of borrowing and sharing, a cattle owner's household and community benefit to some extent from the services their animals provide. The SFM benefits encountered thus far in this study include access to carriage, ploughing, double ploughing and manure.

An interesting aside related to double ploughing refers to the skills and knowledge required to work with cattle. Bullock ploughing was introduced to these communities only within the past 40 years. There are other areas of Northern region and even Dagbon where it is not common practice. A practitioner in Ypilgu described how bullock ploughing was first taught to some farmers at an externally facilitated workshop about 20 years ago who brought it back to their communities. This is an example of Rogers' diffusion of innovation and Transfer of Technology extension: the innovation came from outside the community and was adopted first by the richer bullock owners who could afford a plough, who still probably benefit most from its introduction. Notwithstanding, the human knowledge capital of the technique and the benefits of shallower ploughing are now shared by the whole community, an example of the overlapping communication elements of Rogers' essentially capitalistic model of innovation adoption and the participatory model compared to it in Chapter two.

6.9.9 Dynamic kraaling

Dynamic kraaling involves the rotation of cattles' night-time tether every two to three weeks on plots around the farm, allowing their manure to fertilise the soil directly. In the past, similar arrangements existed in manure contracts, where a Dagomba farmer allowed a nomadic Fulani to rest on his field in exchange for the manure deposited thereon. As pastoralism has declined this is now much less common, and many Fulani have become sedentary around the study site. Some herd Dagomba cattle, which they rotate around their own farms (Powell *et al.* 1996): those living immediately to the North of Zaazi successfully dynamic kraal their own and Zaazi residents' cattle on their maize farm. Although money was not directly mentioned in figure 6.17, much wealth is implied by ownership of sufficient cattle to practice dynamic kraaling.

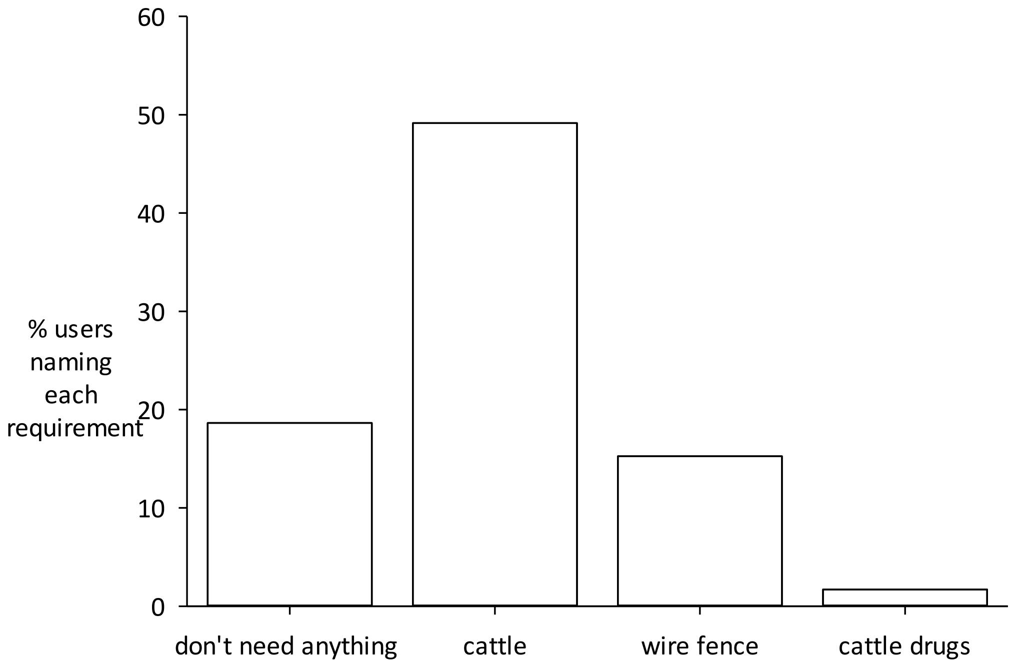

Figure 6.17 Perception of the 13 farmers using dynamic kraaling of its resource requirements.

Two farmers blamed cattle thieves for a decrease in dynamic kraaling, especially further from the house (Clottey *et al.* 2006). A wider type of social capital is therefore also necessary for this practice, incorporating trust within and between communities and tribes. As a result of this fear, cattle are tethered on the *sanbanni* farm, so even if they are owned by junior household members the whole household derives benefit from the manure as they consume the landlord's maize grown in this field. In this sense, as conjectured in Chapter three, the dynamic kraaling system usually reflects the traditional organisation of reproduction at the household level. There are occasional exceptions: Alhassan Napambong in Ypilgu reported how in 2007 his wealthier neighbour Yapalsinaa agreed to tether his large herd on Alhassan's *sanbanni* field. It is not known whether Yapalsinaa was expecting some kind of deferred repayment, so this example shows dynamic kraaling can be part of a village scale system of reciprocity, but could also come the closest of all the SFM techniques examined thus far to a participatory solution. This situation illustrates again the indistinct boundaries between different ownership and usufruct systems: once more, financial capital and individual ownership provide an opportunity for traditional sharing as well as semi-participatory solutions.

6.9.10 Inorganic fertiliser

The capital requirements of fertiliser and compost will be considered in slightly more detail. Figure 6.18 shows the proportion of users of compound and ammonia who considered each of the categories on the x axis necessary to their use of *any* inorganic fertiliser.

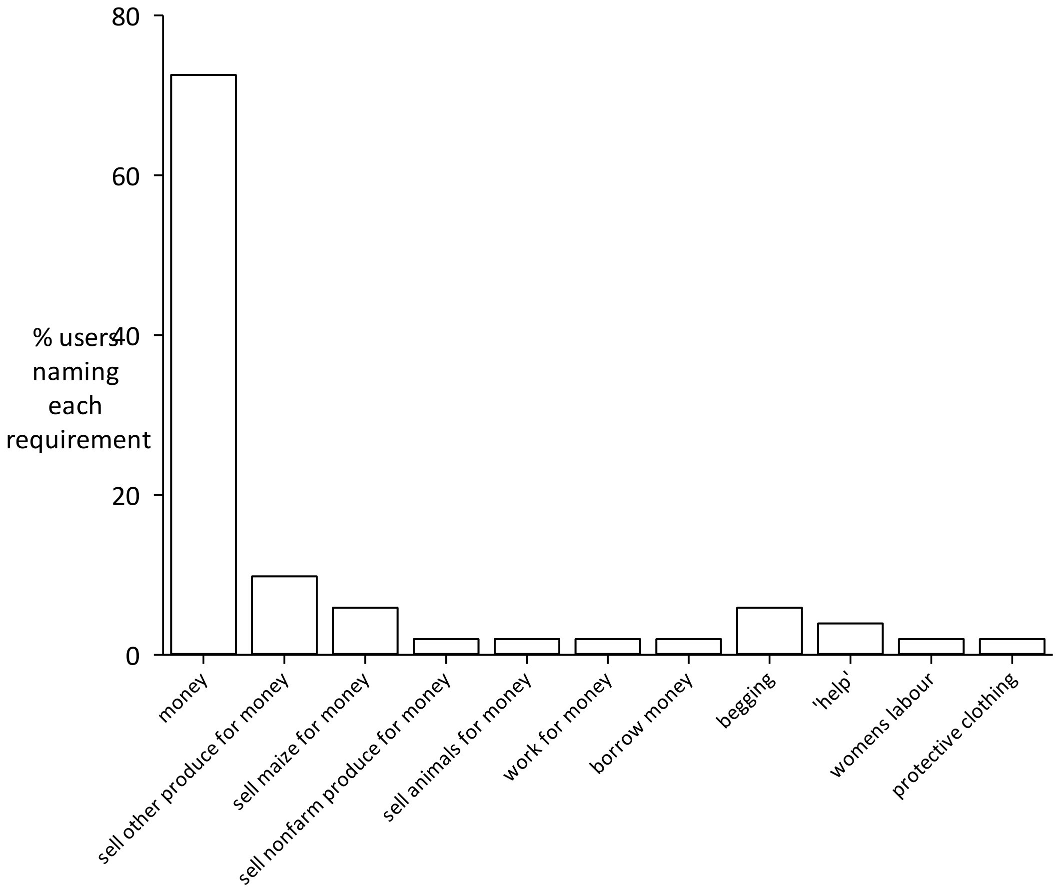

Figure 6.18 Perception of the 60 fertiliser users of its resource requirements.

The immediate impression made by figure 6.17 is that as about three quarters of fertiliser users named money as necessary for their use of fertiliser, an individual's financial capital is paramount and selling farm produce is the most popular way to obtain that financial capital. This would place the use of fertiliser firmly in the capitalist realm. Excludable, subtractable goods are indeed best supplied privately: fertilisers, like the cash that buys them, can be used only once by one farmer in one year. It should be noted here that in this regard the individual rather than the household really is responsible. The traditional system involving kinship and reciprocity rarely acts in this market. Household members are extremely unlikely to pool money for the landlord's maize as they do labour. Junior household members in particular must always purchase their own fertiliser, especially if for a cash crop other than maize.

However, the importance of social capital should not be overlooked. One in ten farmers said they would try to 'borrow money', 'beg', or ask for 'help' indicating they considered the use of some form of social capital necessary to obtain fertiliser or the money to purchase it with. The words 'borrow' and 'beg' imply the importance of the traditional system. However some further investigation into the nature of the social capital indicated by these responses is required, in particular the response 'help' (*'suŋsim'* in Dagbanli).

Those who responded thus illustrate the problem described in Chapters four and five with asking this question - 'help' and 'support' are Ghanaian euphemisms for cash, and some farmers chose to use this question as an opportunity to ask for money: when asked exactly what help they needed for any fertilisation strategy replied 'anything you would like to give me'. This optimistic outlook is probably what led them to refuse to be any more specific than to say they need *'suŋsim'* to be able to apply fertiliser.

Another explanation for this response is that various organisations, (including local NGOs, the Lowland Rice Project, the Millennium Challenge Account, the Ministry of Agriculture, fertiliser companies and private individuals) regularly 'loan' fertiliser to farmers at the start of the farming season, agreeing repayment after harvest. This transaction was also termed *'suŋsim'* by farmers. In 2010 fifty farmers in Ypilgu accepted help from the local financial NGO Centre for Agricultural and Rural Development, funded by the Millenium Development Agency, who loaned 50kg of compound fertiliser to farmers in exchange for one and a half bags of maize, and 50kg of ammonia for one bag. The sanction for non-repayment was non-eligibility to borrow the following year. The NGO required a group of 50 farmers to form an association, so again here social capital acts to allow participatory group members access to another form of capital, in this case the financial capital of a more powerful money owner - the NGO. Such NGOs evidently were amongst those who see that the state's capital rarely reaches farmers and therefore wish to provide a route for the farmers to tap the 'community's' social capital in order to provide alternative access to that cash and to the market. As the money was ultimately from the Millenium Challenge Account, the government did play a role, using its political capital to curry favour with the American government and financial institutions that backed that project.

These transactions are particularly interesting in terms of the systems of capital use and development paradigms they suggest as they definitely involve two and possibly three systems. Farmers participate with each other at the community level, using bonding social capital to establish formal groups unrelated to the traditional system. These participatory groups enable them to enter a capitalist marketplace where they make deals with an outside lender using bridging or linking social capital: a parallel can be drawn with the participatory mechanism used to gain access to the donkey cart provided by the researcher. In the fertiliser loan system, the capital of the state is involved at the international level in a coproductive role as it aims to facilitate market access.

On the theme of the market, few of the fertiliser lenders are doing this for purely altruistic purposes - the maize they receive at harvest time will be stored and sold when the price rises to between 30 and 60 GhC a bag the following 'lean season'. NGOs and private loaners alike use these profits to cover costs and accumulate money. Thus, when identifying the mechanisms through which farmers gain access to fertiliser, the capitalist system interacts more with the participatory and state systems than with the traditional system so central to all the other SFM techniques thus far examined. To the extent to which such participatory groups interact with the market they may be less equitable - Gray (2005) describes how Burkinabe farmers similarly formed groups to get access to cotton company fertiliser, but those with less land, or who could not manage the risk of incurring the debt required to grow cotton in the first place, were precluded from joining.

Some farmers were able to say how many bags of fertiliser they had bought and borrowed, confirming that the credit market is important: Table 6.18 shows that for these farmers, about a quarter to a third of fertiliser was borrowed in 2010.

Table 6.18 Proportion of each type of fertiliser borrowed and bought.

	Ammonia	**15:15**	**23:10**	**Total**
Percentage of bags bought	64.3	74.5	100.0	71.2
Percentage of bags borrowed	35.7	25.5	0	28.8
Total subsidised amount loaned (Ghc)	460.2	655.4	0	1115.5
Total subsidised outright spend (Ghc)	828.3	1912.6	173.9	2915.6

As the majority of the fertiliser debt was repaid in maize, which was collected in the villages, transaction costs (e.g. transport to the market) are lower and entry into the financial marketplace does not necessarily require cash, so is more feasible.

State policies have a greater effect here than hitherto seen in this study, and not only in the provision of loans. Many authors explicitly relate the high costs of fertiliser to the SAPs that restricted the state's contribution of financial capital by cutting subsidies (Powell *et al.* 1996; Sanchez *et al.* 1996; Cofie *et al.* 2005; Bayorbor *et al.* 2006) and investment in extension services and transport infrastructure (Breman *et al.* 2001; Abunyewa *et al.* 2007; Waithaka *et al.* 2007). However, simultaneously, indirect measures like relaxed import tariffs allowed more fertilisers into the market, and current policy is to promote fertiliser use within ISFM. As described, fertiliser was directly subsidised in 2010 and 2011, a change to the coupon system that had run in 2009. Without the subsidy a bag of compound would have cost 48 GhC and ammonia 36 GhC in 2010, and 56 and 40Ghc respectively in 2011. With maize selling for 20-45 Ghc a sack depending on the season, a farmer would have to yield 3-8 sacks/acre to break even, considering the cost of ploughing. Comparing this to actual yields of 4-9 sacks/acre in the study site shows the risks involved. Subsidy is the most important route through which the state influences SFM practice and its influence far outweighs that of agricultural extension, the state's other input into smallholders' SFM activity at the village level. By making the subsidised loan a repayable amount, the state's financial capital therefore acts as another access mechanism to the lenders' financial capital and thus the market.

However, farmers' reliance on the state for subsidy also means fertiliser use is risky in a sense other than agroecological. A common comment in interview was along the lines of 'if you use fertiliser one year you must use it the next year or your crops won't yield'. When the government removes or reduces the subsidy, as is planned for 2015, farmers will struggle to use fertiliser in consecutive years. More fertiliser may be loaned in schemes such as those described above, the overall amount used will decrease, and yields on unfertilised fields will be minimal.

Ostrom (1996) lauds the interaction of such institutions as the state, NGOs and participatory groups as 'coproduction', and this can be interpreted as endorsement of the cooperation between the different systems of capital access they imply. Yet Chapter two described how some criticise neo-liberal institutions like the World Bank as co-opting the participatory ethic through use of the concept of 'social capital', absolving the state from responsibility for service provision (Fine 1999). Indeed, arrangements like membership of farmers' associations to gain access to fertiliser could give a false sense of autonomy when in fact entry into the global marketplace exposes smallholders to the vagaries of externally determined prices. Yet this chapter has shown that when the two co-exist, access to a range of capital use systems can mean farmers have more chance of being able to choose the one that most expediently meets their needs. More relevant to this situation, it may be necessary for two systems to combine in order to facilitate access to an external and otherwise unobtainable source of capital. Fine's argument thus does have weight, in that participation is being used to give farmers access to the less sustainable solution of fertiliser and the unpredictable effects of the market. However, his argument is overridden when the situation is analysed from a wider perspective of an ISFM solution: farmers need market access to some fertiliser as part of a range of techniques in a diverse, flexible strategy that also incorporates subsidy and compost.

The specific question of subsidy divides opinion further, with World Bank authors like Morris (2007) cautioning that it distorts markets and makes smallholder practice unsustainable. On the other hand, the case of significant fertiliser subsidies in Malawi is often cited an example where state intervention has led to positive yield increases (Adesina 2009; Dorward and Chirwa 2011), and the Ghanaian government is taking that line towards their version of market promotion through coproduction. Such coproduction is more evident for the use of fertiliser than for the ostensibly lower capital input of organic amendments.

6.9.11 Organic amendments

Figure 6.19 combines data for users of all organic soil additions - compost, manure and refuse. This is because when the results were disaggregated, the majority response for every type of amendment was that a donkey cart was required.

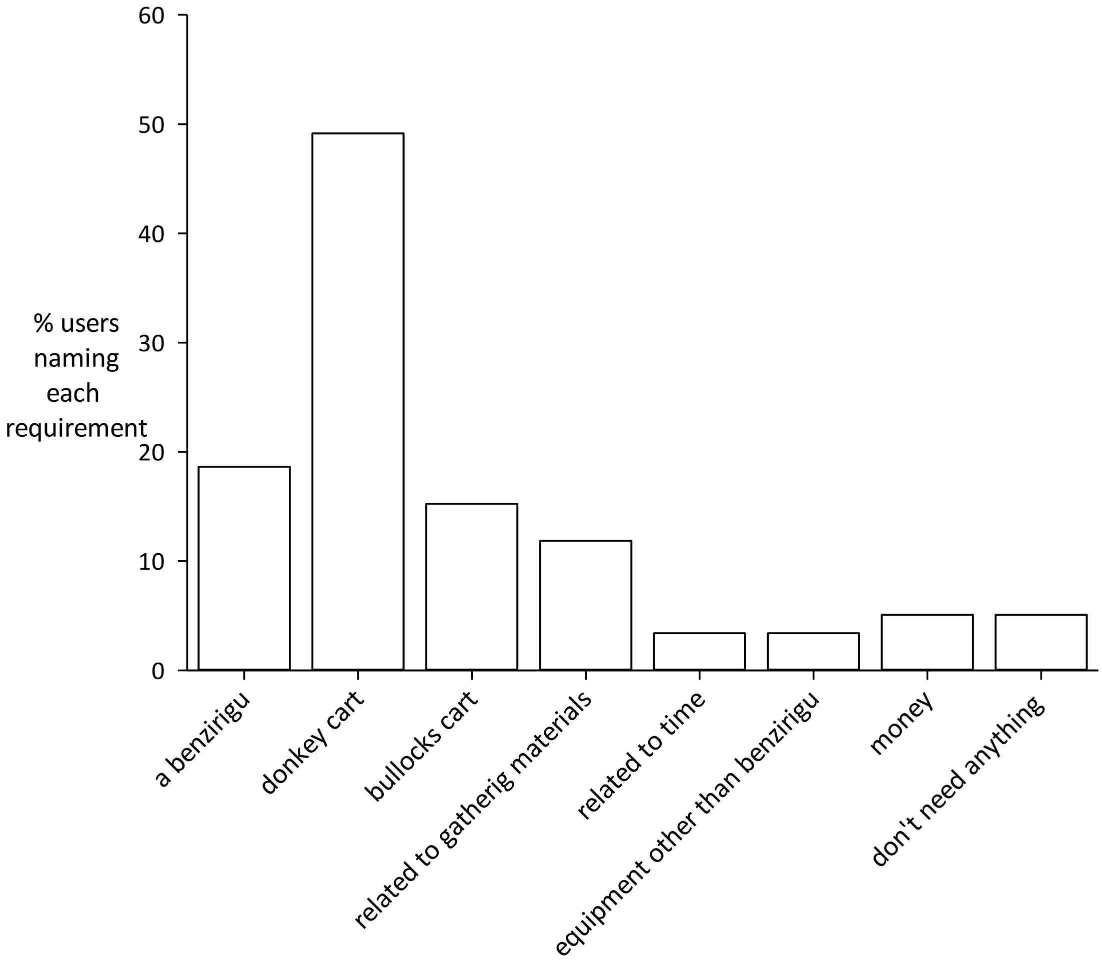

Figure 6.19 Perception of the 60 users of compost, manure and refuse of their resource requirements.

Nevertheless, before comparing the requirements of organic fertilisers to inorganics, a brief exposition of the differences between manure, compost and refuse should be made because this provides an opportunity to examine their different advantages and drawbacks and thus the implications for farmers with more and less capital. In practice, farmers draw on a range of solutions as is convenient, and the definitions of three types of organic amendment overlap as they vary widely in composition and process.

6.9.11.1 Manure

Manure is the most commonly used organic fertiliser, especially in the savanna as opposed to the forest zone (Quansah *et al.* 2001), as it has a higher concentration of available nutrients, particularly ammonia, than green manures (Drechsel and Reck 1997; Harris 1998) and its use requires less labour than composting.

It has been established that richer farmers own more livestock and therefore have more access to manure. Dagomba boys traditionally herd their father's cattle but larger owners may employ herdsmen, usually Fulanis. Traditionally these herdsmen had unlimited access to the herd's milk and manure (Hill 1970) but Karbo and Agyare (2002) note that Northern Ghanaian cattle owners' need for manure is increasingly limiting the herders' use. Manure itself is a subtractable good like fertiliser - its use by one person means no other can benefit from it. It is almost as excludable, although various usufruct systems pertain in different contexts: in the study area it is usually used only by the livestock owner or, with their permission, their household members. A private ownership system thus dominates manure use, hence the development of the markets recorded by Ramisch (1999) where farmers exchange manure for its transportation to the field by cart owners, replacing the traditional manure contracts that have existed between settled farmers like the Dagomba and herders like Fulani in West Africa for centuries (Karbo and Agyare 2002).

Such issues relating to the economically determined availability of manure are compounded by chemical drawbacks. Despite their more measured release over the long term, the immediate availability of nutrients is lower from manure than fertiliser, especially in the first year after application. Recommended rates of manure application are between 4 tonnes/ha (Harris 1998) through 5 (de Ridder and van Keulen 1990) to 10

(Karbo and Agyare 2002), although bearing in mind the heterogeneity of manure in terms of nutrient quality and water content as well as the various modes of application mentioned above, such blanket recommendations are of dubious utility. Nevertheless, under most systems, apart from intensive crop livestock integration, the low quantities and poor quality of manure available to smallholders as well as the lack of tools with which to collect and carry it prevent them attaining adequate rates of application across all their fields (Millar 1999; Abunyewa *et al.* 2007) and this is one of the main factors leading proponents to advocate the ISFM strategy of combined application.

Like all organic amendments, manure use involves labour to transport it and if household labour is used this invokes the social capital inherent to the traditional household economy.

6.9.11.2 Compost

The composition of compost varies even more widely than that of manure, and the types of exchange involved in its use also differ. Definitions of ‘compost’ vary between authors: Harris (1998) describes a mixture of pure ‘dung’ and plant matter as ‘manure’. Here ‘compost’ refers to a decomposed mixture of plant material and sometimes manure. It varies from a simple mixture of manure and bedding, stored for a few weeks to rot, to a complex, well decomposed mixture of crop residues, household wastes and manures, and can therefore have a C:N ratio between that of manure and green manure. As N and P concentrations are higher in manure than crop residues, compost is primarily a method of bulking up rather than entirely replacing manure and of providing a framework for the retention of soluble nutrients.

In Dagbon the residues are usually collected into a pit, which retains moisture better, or a heap that uses less labour. Both entail less capital investment than building cement walls within which to contain the rotting material: mud walls are unpopular as they wash away in the rains and have to be remade annually. The extent of its decomposition further affects the efficacy of compost. Farmers often incorporate semi-decomposed compost into the soil if they been unable to gather it in time to allow it to rot before spreading, or to keep it damp enough for the two to three months necessary for effective decomposition. Decomposition in the field could then release heat and nitrogenous by-products less available and more toxic to young plants. However, this only rarely affects seedlings in the study site, possibly due to rapid rates of decomposition under hot, aerated and sometimes humid conditions in the few days between its incorporation and sowing. A further concern is that semi-decomposed compost, like manure, will also contain weed seeds which are killed in the thermophilic stage of decomposition (Millar 1999), and this is a common observation in the study site.

Individuals usually make their own compost heaps containing the manure of their own animals and use their own labour to collect, turn and carry it. There is rarely a pile for general household use. Compost is thus still a subtractable and rather excludable good, but, as it contains less manure, is linked less to animal ownership and financial capital than to the human capital necessary to produce and transport it. If household scale traditional labour sharing arrangements are involved, intrahousehold bonding social capital is implicated. Therefore, like manure, compost involves the traditional as well as the capitalist market, with slightly more emphasis on the former. It can thus be considered a more appropriate technology for those who lack the financial capital to own many animals - or the interhousehold bridging social capital to engage in the manure market. Cash is, however, still useful to provide digging, turning and transport tools (Ouedraogo *et al.* 2001).

6.9.11.3 Household refuse

Families throw refuse into a pit behind every two or three houses. The composition is affected little by the wealth of the households, comprising groundnut shells, ash, household sweepings and feathers, and the pit is used as a children's toilet. Maconachie (2007) observed poorer farmers in Kano close settled zone who owned no livestock substituting such household refuse for manure, as do Dagomba farmers. This requires only the human capital necessary to convey it from the refuse pit to the field, accessed primarily through the traditional intrahousehold labour market, and thus the social capital of the person to whose farm it is being conveyed. Farmers consider household refuse or *'tampooli'* inferior to purpose-made compost for three reasons: firstly, its nutrient content is lower. Secondly, as a result of this, it is less long-lived. Thirdly, weed seeds are abundant, particularly *Striga* and another farmers referred to as '*bochaa*', probably because, unlike compost and manure which actively degrades, the *tampooli* heap never heats up sufficiently to kill them. *Tampooli* also contains a higher proportion of inorganic residues, but as this has little effect on productivity farmers rarely perceive it as a problem.

The less capital is invested in their preparation, the poorer in nutrient value and less excludable organic amendments become, and they are thus less related to capitalist use systems. T*ampooli*, although still a subtractable good, is almost non-excludable, making it similar to a common property resource. Thus, although the traditional economy is involved in the transportation of all organic amendments, it plays proportionally more of a role the less capital is involved in their preparation. Farmers' responses echoed this to some extent: one farmer explicitly stated that manure use required money and another said *tampooli* use had no capital requirements. However, by far the most striking trend was, as mentioned, that more than 80% of farmers named a donkey cart as necessary to the use of each amendment, hence why the use of all organic waste is combined for this analysis as 'compost'.

Individual and household human capital is important to the use of organic amendments: 15% of responses referred to time spent making compost and gathering materials. As only 5% of respondents specified that money was necessary to use compost it could seem financial capital is less relevant, especially as the transportation of organic residues in particular does necessitate the traditional exchanges of social and human capital that occur at the household scale. However, the *benzirigu* so necessary to compost carriage is a form of physical capital which can be purchased or hired with financial capital, so the capitalist system is also important for effective compost use. Chapter five found that the financial capital necessary for individual ownership of a *benzirigu* can to some extent be replaced by group social capital when it is owned by a group, but that the traditional system of begging and borrowing has a more important role to play in facilitating access to lumpy physical capital privately owned by richer individuals.

Most of the SFM techniques examined bear more resemblance to compost than fertiliser in that individual financial capital is more important in facilitating their use, linking them to the capitalist and traditional systems. Table 6.19 summarises the capitals farmers most commonly considered necessary for each SFM technique and, as in table 5.4, the system of capital use implied by those commonest answers is indicated in column 6.

Table 6.19 SFM strategies, their most commonly named requirement and implicated capitals.

SFM strategy	Most named requirement	Percentage practitioners naming it	Capital implicated	Source	Capital use system
15:15:15	Money	86	Financial	Individual	Capitalist
Ammonia	Money	70	Financial	Individual	Capitalist
23:10	Money	63	Financial	Individual	Capitalist
Compost	Donkey	53	Physical	Individual/ group	Capitalist/ traditional/ participatory
Manure	Donkey	100	Physical	Individual/ group	Capitalist/ traditional/ participatory
Tampooli	Donkey	67	Physical	Individual/ group	Capitalist/ traditional/ participatory
Dynamic kraaling	None	53	None	N/A	Traditional
Crop rotation	Seeds	30	Financial/ natural	Individual	Capitalist
Fallowing	Land	41	Natural	Individual	Traditional
Double ploughing	Money	64	Financial	Individual	Capitalist
Green manure	Seeds	100	Financial/ natural	Individual	Capitalist
Herbicide	Money	46	Financial	Individual	Capitalist
Pollarding	Knife	47	Physical	Individual	Capitalist
Weeding	Pay *kparaba*	14	Financial	Individual	Capitalist
Ridging	Hoe	24	Physical	Individual	Traditional

Columns 4 and 5 show that farmers generally perceived a lack of physical and financial individual capital limited their SFM activities, preventing their entry into the marketplace of private ownership. The only activity where most practitioners stated they did not need assistance was dynamic kraaling, an activity open only to cattle owners and thus reliant on those individual’s physical capital.

The excludability and subtractability of different SFM techniques go some way towards explaining why different capital use systems are differentially appropriate for them.

SFM techniques that depend upon ownership of the physical capital of cattle, land, *benzirra* and inorganic chemicals are more subtractable and excludable, and thus fit Polski and Ostroms (2009) description of the private and 'toll' goods that generally function well within the capitalist system. As they cannot be easily shared, and access to them is restricted, the owner or seller has power over the capital transaction that must be effected for their use. On the other hand, crop rotation, green manuring, ridging and weeding and, for now, pollarding are more constrained by the availability of labour, as the physical resources they require - leaves and self sown crops - are as yet abundant and thus non-subtractable. The availability of labour is therefore what characterises them as generally more public and common goods, especially within a system where obligations render that labour more available to peers and seniors, and situates them more within the traditional realm. Only *tampooli,* which involves just the human capital input required to haul it, approaches the status of a common property good as a result of the minimal amount of capital put into its production. This is summarised in table 6.20.

Table 6.20 Subtractability and excludability of various SFM techniques.

SFM technique	Subtractability	Excludability	Type of good
Crop rotation	None	Low	Public
Weeding	None	Low	Public
Ridging	None	Low	Public
Green manuring	None	Low	Public
Pollarding	Less	Low	Public
Double ploughing	Less	High	Toll
Dynamic kraaling	More	High	Private
Fallowing	High	High	Private
Fertiliser	High	High	Private
Manure	High	High	Private
Compost	High	High	Private
Tampooli	High	Low	Common

Table 6.20 is a guide based on the data collected in this context, not a definitive typology. Differences between different farmers' description of their practice highlighted that it is not possible to describe all instances of a practice as the same type of good or service. Their subtractability varies depending on the amount and accessibility of the capital resources they rely on, and their excludability changes according to the way those resources are held and accessed. The definitions of

practices overlap for three reasons: firstly, many involve not only a resource but also an action, e.g., carrying compost to the farm, and the terms of access to that labour are as variable as the terms of access to physical resources. Secondly, these terms of access may vary between households or communities. For example, in Dagbon cattle are usually privately owned, making them excludable, but households adhere to this to differing degrees. Likewise, further from Tamale soft-leaved trees become more abundant and thus less subtractable, and the ability to pollard therefore becomes more a public than a common property resource. Thirdly, the changing environment that frames this study means the availability of the capitals each SFM strategy relies on may change over time as well as space. *Tampooli* can be used again as an example of such context specific classification. *Tampooli* itself is considered a common property resource, but when access to large volumes of it relies on the toll good of the fairly subtractable donkey and bullock cart, it also becomes a toll good.

This consideration of context is the final key to understanding why multiple capital use systems can be used for each SFM technique.

Table 6.19 indicates that the capitalist system is most important for use of the subtractable and excludable good of fertiliser. However, in the study communities, state and participatory mechanisms played a role in facilitating farmers' access to it. This can be explained not only by its characteristics but also by the situation of relative capital dearth in which they are encountered.

There was insufficient financial capital available within these communities for all individuals to have access to the fertiliser they needed. As fertiliser relies on cash, the traditional system could not ameliorate this situation: financial capital and fertiliser is subtractable so cannot be used in the same season by borrower and lender. The state, and other organisations, recognised this and provided the subsidy and the participatory coproductive mechanism that allowed farmers access to external financial capital. *Benzirra*, on the other hand, are less subtractable, and the wealth accumulating in the community by 2011 was sufficient for individuals to purchase them, facilitating the traditional system. This confluence of the nature of goods, the types of capital they require and the local and national contexts they occur within illustrates once again the interplay of different scales.

Private financial and physical capitals are considered necessary for the SFM strategies most highly rated by farmers in figure 6.7. According the farmers in the survey, if endowed with a donkey cart, money or bullocks for ploughing, money to buy seeds and a cutlass to coppice trees a farmer would be able to practice the most effective techniques. However, as was shown in section 6.8, a more important consideration regards the ability to practice any combination of these methods at any time or to adapt them according to different capital availabilities, new knowledge or changing environmental conditions. This section has seen that a range of capitals are required for each SFM technique. Due to the dearth of financial and physical capital, farmers substitute them for each other to get access to the methods they consider best, whilst substituting those different methods themselves within their integrated, weakly sustainable strategies. The implication of this is that, on a wider scale, systems of capital use and development paradigms also coexist. This happened for both composting and fertiliser as farmers used the traditional system, and, to a lesser extent, participation, to access capital accumulated within or outside their communities. When this is a synergistic interaction, as with the fertiliser group mechanism and the borrowing of privately owned *benzirra*, it represents coproduction.

The livelihoods framework makes it easy to examine these types of exchange of different types of capital. Yet the concept of modes of production considered briefly in Chapter two also enriches the analysis. The importance of financial capital in facilitating both modern transport and SFM techniques is analogous to the gradual acceptance of more of the characteristics of capitalism (Clark 1979) as production of cash crops, as well as reproduction of subsistence, increases in importance within the Northern Ghanaian smallholder economy.

It has been repeated throughout this work that aspects of many livelihood systems and modes of production articulate, and the capitalist mode has increased in importance in Northern Ghana since the state of Dagbon conquered the original acephalous peoples of this area like the Konkomba (Tsikata and Seini 2004; Ahorsu and Gebe 2011). This ongoing trend is reflected in the 21st century repositioning from the ‘second’ to the ‘integrated’ paradigm of SFM: whereas the first emphasised the organic component of a combined and efficient fertiliser treatment, the latter valorises market relations as a dominant facet of the interdisciplinary approach, with financial exchange facilitating the inorganic component of the mixed strategy. The Ghanaian government's policy of mechanisation and modernisation also points towards a commercialised capitalist agricultural future, but one where the state plays a role, as with the subsidised tractor purchase loans that facilitate farmers' entry to a private hire market.

Social capital has been seen to be important in both traditional and participatory systems as an access mechanism to externally accumulated capital. It is, however, difficult to judge whether it is easier to use social capital to replace the financial capital necessary for compost *benzirra* or that necessary for fertiliser. It is to this question that section 6.10 will turn, in order to assess which would be the best target for social capital.

6.10 Substitution of capital - Can social and human capital substitute for physical and financial?

It has been seen how, as well as practising a range of techniques, farmers make capital substitutions within different systems. Social capital in particular is used in both participatory and traditional mechanisms to replace individuals' financial capital, giving access to composts and fertilisers. The first important question is therefore whether one of these systems is more amenable than the other. Following from that, it is useful to ask which SFM solution provides the best value for expending a certain amount of capital. The answers could act as a guide for intervention.

Synthesising table 6.19 with the findings of Chapter five helps to answer the first question. Figure 6.18 shows that primarily, farmers perceive that compost application requires carriage. Chapter five found that, currently, those who managed to carry the most compost were those with more *individual* access to both human and physical capital through capitalist and traditional systems (tables 5.8, 5.9, 5.10, 5.12 and 5.15).

Three examples of farmers who managed to apply large volumes of compost to their farm illustrate this trend well. Mr Yahaya, who had been given his own donkey by OIC in 2010 and bought a second cart for it in 2011, was described in section 5.7. Slimbongna, one of those who purchased a bullock cart in 2011, owns five cows himself with a total of 17 between him and his six adult sons. Botongna, who applied the highest volume of compost of any farmer in the whole survey to his experimental field, used six boys to carry manure from the ten cows his house owns to his two acre *sanbanni* farm. None of these rich users of high volumes of compost used the group donkey to carry a disproportionate amount. In their cases, as the statistics in section 5.7 on the whole sample show, successful application of much compost is still based on an individual and their household's social and human capital rather than the bonding capital held in a group. In other words, the traditional mode of economy is still more important than the formal participatory solution in terms of facilitating compost use, especially as incomes rise and more individuals purchase vehicles. Participation does provide an alternative route through which those with little social capital could access physical capital. It is not however, an easy option. Nor is it always entirely egalitarian - both those who advocate (Mayoux and Chambers 2005) and critique (Cooke and Kothari 2001) participation note that the costs of group participation (Oliver 1984; Wandersman *et al.* 1987; Prestby *et al.* 1990) mean it is differentially open to individuals.

Social capital also facilitates fertiliser use, and here the linking capital that acts within the participatory system is more successful in allowing farmers to access the capitalist market. The success of participatory groups in this situation, combined with the survey data showing that most farmers were able to borrow at least one bag of fertiliser, is evidence that participatory rather than traditional systems may be the most successful way to provide access to very excludable and subtractable goods in situations where the requisite financial capital is lacking. Financial capital is therefore not as inaccessible as it may seem to be were the evidence based solely on farmers' interview data.

Of these two systems, the traditional seemed preferable to farmers. Due to its highly subtractable and excludable nature, and thus higher relative cost to the individual, fertiliser could largely only be accessed through the participatory system. Both traditional and participatory systems, on the other hand, could provide the less subtractable *benzirra*, and the prevalence of the traditional system indicated that farmers found such borrowing and sharing more amenable than the participatory style group. The nature of a good therefore determines through which system social capital may be used to access it. In this case, if there is a choice, the traditional system is preferred. It was only the cost of fertiliser and its subtractable nature which meant individuals were forced to adopt participation.

An example of the importance of context is to be found in Zaazi, where borrowing fertiliser or the cash to purchase it is more common than compost making, as cash, or at least credit, is more available than human capital here. Such borrowing resembles the traditional economy and could be due to the dominant presence in this village of the market for irrigated vegetables, facilitated by the village's proximity to a water source. This echoes how, in Zaazi, access to more hire donkeys meant the group was less popular. This makes the role of diversification apparent, a reminder that as compost is just one aspect of fertilisation for intensification, intensification is just one aspect of a livelihood.

To answer the second question of the comparative benefit of different SFM techniques, even if social capital is necessary for access to both organic and inorganic fertilisers, three main factors mean that compost outcompetes inorganics. Firstly, it can give better yields in the year of application, probably due to non-nutrient benefits like better soil structure, water retention and pH balancing. Secondly, its effects last for up to three years. This reduces the risks posed by the possibility of unavailability of fertiliser in consecutive years as a result of subsidy withdrawal or distributional problems. Finally, table 6.21 shows that, partly due to this longevity, compost is annually cheaper than fertiliser.

Table 6.21 Three year cost-benefit analysis of compost and fertiliser per acre.

	Fertiliser	**Compost and hired donkey cart**	**Compost and bicycle**
Cost of 25 donkey cart trips (GhC)	n/a	25	n/a
2010 subsidised compound cost (GhC)	54	n/a	n/a
2010 subsidised ammonia cost (GhC)	18	n/a	n/a
Labour time (person-hours)	About 5	About 50	About 200
Payback time (years)	1	3	3
Total time cost/year (person-hours)	**5**	**16.6**	**66.6**
Total cash cost/year (GhC)	**72**	**8.3**	**0**
Labour cost (Ghc/hour) (see note)	**0.5**		
Total cost/year (GhC)	**74.5**	**16.6**	**33.3**

Note: Paid *kparaba* or 'by day' rates are between 1 and 2 Ghana cedis for a day's labour, which will be about 4 hours. Manual labourers outside the farm are paid slightly more - in 2011 workers laying a water pipeline in Savelugu near Zaazi were paid 5GhC for a 6-8 hour day.

Compost outcompetes fertiliser in financial terms. This is not the only measure of effectiveness or feasibility, but many, like the social capital costs involved in borrowing a *benzirigu*, are impossible to quantify. Nevertheless, table 6.22 summarises the relative advantages and disadvantages of these two SFM techniques.

Table 6.22 Comparative advantages and disadvantages of compost and fertiliser. X=preferable

	Compost	**Fertiliser**
Longevity	X	
Financial cost	X	
Time cost		X
Labour cost		X
Macronutrient addition		X
Soil structure	X	
Water retention	X	

Although compost appears more advantageous, there are still certain absolute constraints to the practicality of its use, such as the time cost of covering one acre of land by bicycle. Some of these constraints can, however, be met. The latter problem, for example, can be circumvented in the absence of a larger *benzirigu* by rotating application of compost to a different third of an acre each year. Some farmers in Zaazi and Ypilgu were practicing this, whereas some, like Abalambei, stated that this was the first year they had considered the benefits of such a strategy as before 'we were just applying it anyhow'. Compost use may therefore be feasible on areas of up to an acre a year.

As compost outcompetes fertiliser in terms of yield, the main barrier to its effective use is currently not its running costs but the gross financial capital necessary for *benzirigu* purchase.

Considering the long-term advantages of compost alongside the availability of subsidised and loaned fertiliser, using both as part of a combined strategy seems most practicable and advantageous. The other strategies farmers use also have benefits which neither compost nor fertilisers have and may be differentially accessible to farmers with varying capital capabilities.

6.11 Summary

This chapter has answered the second research question, 'What are the comparative benefits and capital requirements of different SFM strategies, in particular composts and inorganic fertilisers?' It has shown that even for those few farmers who have enough money to apply fertiliser at the recommended rates and on time, composted maize generally outperforms that fertilised inorganically. This indicates that even if financial capital is available to supply inorganic nutrients to the soil, the added benefits of compost, such as improved soil structure, higher pH and better water retention capacity, lead to maximum maize yields.

Farmers need individual financial capital to apply fertiliser, which is ultimately supplied through the capital market. Coproduction occurs as access to it is assisted greatly by a state subsidy. For those with insufficient cash of their own, using community social capital to form a participatory group that accesses external financial capital is another option for the subtractable, excludable good of fertiliser. However, if farmers wish to obtain maximum yields by borrowing or hiring *benzirra* to carry compost, use of individual capital in the linked capitalist and traditional systems is more important. Participation for access to compost is less common, though possibly sometimes more equitable. Thus, as more people buy large *benzirra*, stratification may work to make compost more accessible to the rich and fertiliser an inferior option for the poor. Considering the agronomic advantages of organic matter incorporation, investing such individual financial capital in high volume *benzirra* for compost carriage would deliver a better return than fertiliser.

In addition to compost and fertiliser, farmers draw upon a range of other SFM strategies, depending both upon the agronomic advantages they offer and the capitals available to them at any particular time. The importance of strong sustainability and recognition of the limiting nature of financial capital and market access implies that the second paradigm of SFM, and thus techniques that promote SOM formation, is more relevant to this situation. Ultimately, flexibility to pursue any of these SFM strategies at the right time is the optimum. However, financial capital is not always sufficiently available to facilitate any form of low risk, timely fertilisation an individual may wish to pursue; as seen in Chapter five, animal drawn *benzirra* are not yet quite common enough to facilitate carriage of everyone's compost, and there is not enough cash in the community for all to buy sufficient fertiliser. In this situation, participatory group formation is a necessity rather than a choice.


Intercropped, composted and fertilised maize in Zaazi

Chapter Seven

Conclusions: Contexts, coproduction and coexistence

7.1 A context specific approach

This study has examined the socioeconomic and agroecological aspects of SFM and IMT in the Northern Ghanaian Guinea Savanna, examining qualitative and quantitative data collected by farmers and the researcher with the intention of answering three research questions.

The first, 'How could smallholder farmers best carry compost to their maize farms and what are the capital requirements of that strategy?' was addressed in Chapter five. A survey of the relative efficiencies of different transport options and farmers' interview evaluations of their relative advantages and capital requirements found that farmers preferred to access large animal-drawn carts by borrowing those acquired by richer community members. When this was not possible, participatory access was an alternative and personal ownership of small vehicles like bicycles was a last resort for timely compost carriage.

The second question, 'What are the comparative benefits and capital requirements of different SFM strategies, in particular composts and inorganic fertilisers?' was tackled in Chapter six. Combining plant growth and yield parameters with soil nutrient tests, a water retention assay and farmer interviews showed that the water retention properties of organic fertilizers meant they produced optimum yields, but access to a variety of fertilisation techniques reduced agroecological and economic risk. Most SFM techniques relied on personal financial capital accumulation, but participation and state input played a role in fertiliser use.

Both Chapters five and six began to consider the third question, 'Which elements of different systems of capital use and related development paradigms can best facilitate effective SFM in Dagbon?', and that process is continued here.

This final chapter will synthesise the findings of Chapters five and six, reviewing their practical implications and going on to emphasise the elements of different capital use systems and paradigms they imply, thereby shedding further light upon the question of which are most relevant. The chapter confirms that the various types of development paradigm are differentially useful in different contexts. In this case, two important differences between contexts were the level of available capital and the extent of subtractability of the resource. These determine the system through which farmers may best fulfil their needs, which here were to fertilise their soil effectively. On a theoretical level, this finding leads to the reflection that a framework built around the idea of context specificity may be more useful than one that starts with a typology of development paradigms. Within the SFM and livelihoods contexts, such an approach is likely to lead to more expedient and sustainable outcomes.

7.2 Mitigating methodological limitations

Working closely with farmers in the field entails multiple limitations - similar to those that the farmers experience in the environment and that limit their practice. Insufficient capital for necessary equipment, language barriers, lack of controls and control in field experiments and non-randomised sampling by participants were all described in Chapters four, five and six. However these were tackled as far as possible through triangulation, especially with participant observation. There was a constant tension between the objectivity and scientific detachment required to perform valid statistical analysis and the richness that close involvement with farmers brought to the data. Ultimately, both quantitative and qualitative data were equally important in revealing novel results. Quantitative measures showed how the water retention capacity of soils, and thus strong sustainability, was of paramount importance in the study site, and participant observation showed how farmers gained access to larger forms of transport as their capital endowments rose, facilitating interaction between capitalist and traditional systems of capital use. However, most importantly, the combination of the two methods was absolutely essential in elucidating how agroecological and socioeconomic factors interacted within farmers' livelihoods. Either alone would not have revealed the full story (Buhl 2005). This combination and triangulation of techniques was the most important aspect of the methodology: and such a sensitive and interdisciplinary approach makes the results credible.

7.3 Practical findings: ongoing co-production and synergy in farmer livelihoods

The central message of this thesis is that although individual financial capital is very important, access to a range of capital use strategies is actually the most critical factor enhancing choice and success in smallholder livelihoods. But alongside this central concern about which systems of capital use best facilitated effective SFM, other theoretical issues were drawn into the discussion. One of these was the question of whether strong or weak sustainability was more relevant. There was a certain amount of capital and method substitutability in farmers' current and suggested IMT, SFM and indeed overall livelihood strategies. This could seem to suggest that weak sustainability had a role to play, and indeed the livelihoods concept could seem to promote weak sustainability in the interchangeably and fungibility of capitals it allows. Yet Chapter six demonstrated that the savanna agroecological context accentuated the advantage of SOM in terms of its ability to retain soil moisture, a function not performed by inorganic fertilisers. Ekins *et al.*'s (2003) idea of strong sustainability is thus a relevant concept in this environment. The fungibility of livelihood strategies does not mean that one can replace another absolutely: rather that access to a range is necessary in order to facilitate smallholders' choice. A related practical theme that resurfaced throughout the results was one of timely practice, usually in order to meet and maximise effectiveness of the rains.

Key examples of instances that illustrate this are: the need to make compost on time for it to degrade fully, to get fertiliser into the soil on time for nutrients to reach plants at the critical growth stages and to apply compost in time to plough and plant before the rains truly set in. These agroecologically determined time constraints inherent in savanna livelihoods are the major factor predicating strong sustainability. In this context, the function of SOM in improving soil moisture retention capacity enhances the agroecosystem's resilience to drought, alleviating the extent to which farmers are subject to agroecogically determined time constraints. These considerations were central in determining the most appropriate SFM and IMT solutions and the capital use systems for implementing them.

The qualitative and quantitative data presented mainly in Chapter six unsurprisingly confirmed the consensus view in the literature that a mixture of organic and inorganic fertilisers is the best SFM strategy. Yet within that, the considerations of strong sustainability meant that in this savanna context, the 'appropriate' use of inorganic fertilisers referred to in the more pro- inorganic ISFM paradigm (Adesina 2009; Vanlauwe 2009) should be read as 'minimal', as Sanchez (1994) originally defined in the second paradigm of soil fertility management.

Beyond these subject-specific considerations of timing and strong sustainability, the appropriate style of capital organisation and the paradigms on which it draws for a given situation were determined by how close people were to being able to fulfil their needs - i.e. how much capital they could access.

Chapter six found that farmers who used fertiliser seldom had enough capital available to be able to fulfil their needs – they applied fertilisers late and in insufficient quantity, generally due to financial capital limitation. They were massively assisted in solving this problem by the state subsidy - the almost sole yet central role of the state in this story. The most effective way to access other externally sourced financial capital in the form of loans and gifts from NGOs and MOFA was to form participatory groups. This was necessary as there was insufficient financial capital in the village for people to share and borrow it within the traditional system and hence to provide everyone with enough of the subtractable good of fertiliser. Coproduction is evident here as the statist, participatory and capitalist solutions interacted to improve access to inorganic fertiliser, a high external input SFM technique.

Compost, the preferred, more sustainable technology, actually was not as 'low input' as often claimed in the agroecology and LEISA literature. In order to use this technique, individuals also needed capital – the natural capital of raw organic materials, social capital as an access mechanism to human capital with which to turn them into compost, and, most crucially, financial capital with which to access a mode of transport.

However, when it came to this critical issue of access to a mode of transport, Chapter five found that farmers in the study communities were more able to independently access the capital they needed to get access to a vehicle than they were to acquire the capital necessary for inorganic fertiliser. As some of them had invested in the large and only partially subtractable good of a cart, the capitalist system based on individual accumulation was more amenable to this situation, especially as incomes rose between 2010 and 2011. Individual accumulation increased access to *benzirra*, not just for the individuals who purchased them but, most importantly, for their community members and kin through the traditional system of sharing and borrowing. Participatory groups were a more equitable, but more difficult, system that acted alongside individual acquisition, providing access for those who lacked the financial and social capital to access the privately owned *benzirra*.

Social capital thus had a role to play in improving access to vehicles for transporting organic fertiliser as well as to inorganic amendments, but more through the traditional system than the participatory system espoused by early proponents of social capital, LEISA and agroecology (Uphoff 2001). Based as it was on inequitable accumulation within the village, this traditional system functioned best when not everyone had enough capital to fulfil their needs fully, but some had enough capital to be able to share - at the cusp between two situations of ubiquitous incapability and self-sufficiency. As it thrived on inequality it was unlike the participatory system, which was more appropriate in the situation of universal incapacity, when no one had enough capital to meet their own needs fully so they had to source capital from outside. Thus the appropriate paradigm for accessing capital depends in part on the level of financial self-sufficiency those within the community have attained. This is as much a determining feature of the context as its agroecology.

On the national scale, all the smallholders involved in this study are in a low income group. Nevertheless there are differences in wealth between them that are highly significant and illustrate clearly how linking social capital emerges from unequal capital endowments. The study has shown that different capitals can best be provided to the diverse array of farmers in any one community if a range of systems of access to them exists concurrently. A mixture of such systems is also necessary to facilitate use of a variety of SFM and IMT techniques in an integrated strategy - not just the most sustainable organic matter and the timeliest donkey cart. Both Chapters five and six emphasised how the flexibilities and synergies inherent in integrated SFM and transport strategies defined those strategies as optimum. In the same way that ideas of strong and weak sustainability continually resurfaced, synergy and choice between strategies were recurrent themes throughout the study. If a range of techniques, capitals and systems of access to them are necessary in facilitating choice, so are ideas from a range of development paradigms: smallholders can and do select which is most appropriate and amenable in their particular context.

It is important to note that coexistence is as important as coproduction. The relationship between individual ownership and traditional sharing was a coproductive synergy that allowed the poorer access to the vehicles of the richer when the overall wealth of the village rose. Thus in a richer context the mixture between traditional and capitalist paradigms is appropriate whereas in a poorer context the participatory paradigm is more relevant. Although Chapters 2 and 3 identified that the participatory paradigm was part of a move away from the modernist ideologies and dichotomies of capitalism, African socialism and political ecology, in the study site participation nevertheless acted in a coproductive way with the state and capitalism, for example as participatory credit groups facilitated access to subsidised fertiliser. However, conventional forms of capital access still existed alongside each other and facilitated each other without changing form - traditional relationships obliged young people to contribute their labour to household compost carrying endeavours, participation was in evidence in the donkey sharing groups and unadulterated capitalism acted in some of the hire transactions. The multiplicity of individual contexts within a setting mean that the possibility of access to any of a range of simultaneously articulating techniques is just as important as the construction of new hybrid systems of capital access that may emerge from synergy between them.

Chapter two described some of the more political objections to the implications of coproduction, for example Fine's (1999) consideration that the concept of social capital could be invoked to excuse the state from any responsibility for development. This interpretation can be applied to the findings that traditional sharing systems meant capital accumulation by rich individuals and the involvement of NGOs in giving farmers fertiliser credit could benefit the community.

However, when addressing the problems of transport rather than SFM, there are fewer alternatives to participation as an 'efficient' short term solution. The compromises of coproduction and coexistence are imperfect but necessary in this case of relatively low capital endowment and state involvement. There is a possibility that the concept of social capital could indeed be used in an extractive and apolitical sense here. Yet in a situation where neither the state nor individual accumulation can meet everyone's needs, to some extent social capital acts to even out the inequitable effects that would occur if the richer owners of large vehicles, for example, did not share that wealth with other community members.

Farmers are currently using a range of methods and paradigms to facilitate effective SFM, and there is potential for both change and improvement. At a practical level, further integration of crop residues, market crop production and livestock husbandry are all possible. The results of the study have confirmed the value of coexistence and coproduction - and indeed any other system that provides a choice of practical and capital use strategies - working in this instance through the mechanisms of time and responding to the importance of strong sustainability. Although there are still capital constraints, farmers, governments, companies and other external organisations like NGOs and research institutes are collaborating to make capital for sustainable production available through a range of techniques and systems.

7.4 Theoretical findings and applicability: context specificity overrules paradigmatic distinctions

Such practical results lead to more theoretical considerations. For these farmers, the participatory paradigm was more appropriate when there was relatively less capital available for them to fulfil their own needs effectively, and the mixed capitalist/traditional solution was more appropriate when a higher level of capital meant they were better able to do so.

This characteristic of the ‘level of available capital’ can be seen as a facet of ‘context specificity’, similar to the physical ‘site specificity’ identified in Chapters two and three as determining the appropriate IMT and SFM strategy. There are other factors that contribute towards the characterisation of the ‘context’ here. To assist in defining these, it helps to reiterate the question that this chapter addresses: ‘Which elements of different systems of capital use and related development paradigms can best facilitate effective SFM in Dagbon?’

Dagbon is the spatial and cultural descriptor of the context, and other factors are the temporal parameters of the situation being addressed, the scale of analysis and the type of resource that is being used or practice performed within it. Here that practice is Soil Fertility Management and the specific components that comprise it are the techniques and tools such as fertiliser, compost and donkey carts that farmers identified as most useful. Critical characteristics of these resources that contribute towards describing the context include their physical characteristics, mode of procurement, excludability and subtractability. Within this study it has been seen that the appropriate combination of techniques, strategies and underlying paradigms varied not just between sites but also between individuals and their situations, although within and between communities and households individuals with similar characteristics participated in similar solutions based on characteristics such as capital availability. This study has shown that the most appropriate SFM strategy depends upon the context, which comprises multiple descriptors and may be defined at a very local scale, rather than implicating one particular paradigm or combinations thereof as most appropriate.

Twentieth century Western distinctions between ' capitalist', 'statist', 'participatory' and other paradigms may therefore be less relevant across the board, not just to this 21st century African situation. A more context specific approach finds expression in 'coproduction': arguably the point at which participation intersects and articulates with capitalism. Considering the benefits of coproduction brings the efficiency argument for participation back to the fore. This does not mean that traditional approaches and paradigmatic typologies are unhelpful or should be abandoned: understanding the role of modes of production (e.g. capitalism) or of conceptual frameworks like political ecology that have been considered within this work is essential in setting a situation in its historical and political context. However it does mean that researchers need to be open to the possibility that elements of all approaches may be helpful and necessary in analysing a particular situation - and more crucially in proposing solutions. Chapter two described an instance in which writers from one school of thought, diffusion of innovation, ignored the existence of another, participation. There has been literature that crosses and contrasts paradigms, for example O' Laughlin's (2002) Marxist critique of livelihoods analyses of Mozambique, but that paper comes down on one side of the fence. Sometimes a compromise approach is necessary and helpful. Significantly, policy makers in poorer places, such as the Government of Ghana, are more likely to take such an expedient approach, instigating policies like the externally funded fertiliser subsidy and credit schemes and the tractor loan system.

This interdisciplinary thesis furthers several bodies of academic work. It proposes an idea of context specific development drawing on a range of paradigms, and it makes a special contribution to the livelihoods literature. The case study acts as a prism through which to compare strong and weak sustainability and illustrates an example of the strengths and weaknesses of participatory development. Its contribution to the SFM debate is especially instructive in terms of illustrating the evolution of a school of thought. As scientific disciplines develop and more information is uncovered they are less likely to make huge paradigmatic leaps. Scientific opinion gradually shifts backwards and forwards as new data are analysed. The evidence from a group of studies pushes the debate in one way or another, suggesting amendments, improving theories, and of course influenced by the dominant political paradigm. SFM in the early days lurched from an external input technologist paradigm to one of pure organic farming, before coming to settle in the middle ground of combined application. This work also exists within that flexible middle space, arguing for a strong sustainability viewpoint that is on the organic side of the combined application debate, but recognising in a conciliatory fashion that the ‘answer’ - and thus appropriate paradigm - is context specific. This viewpoint has resulted from the participatory study design that considered farmers’ socioeconomic as well as their agroeconomic context.

In terms of policy relevance, this thesis has found important differences in wealth between the farmers clustered at the bottom of the income spectrum. Policy is often informed by the experiences of farmers who are significantly wealthier than those who participated in this work. Within the study context, participatory systems rather than individual capital accumulation had the potential to be more relevant to the very poorest. However, rather than proposing an alternative solution for these farmers, the study highlighted the varied solutions that coexist even within such poor communities. It therefore brings a methodological rather than a practical or theoretical message to policy - context specific research should inform context specific solutions, because it is unrealistic to envisage even the poorest smallholders as a homogenous group.

7.5 Interdisciplinary methods for diverse situations

The concepts of coproduction, synergy and choice are integral to research on farmer livelihoods, regardless of the framework within which the research is positioned. Such themes of variety, mixture and connection are also relevant to the methods used - an interdisciplinary approach is invaluable. Livelihoods are affected by and act upon a matrix of concerns that span the boundaries of academic disciplines. This study has made an irrevocable case for a choice of methods in not only in research but also in agricultural practice. Not only does this enable researchers to uncover the most robust results: it also allows farmers to practice the most socioeconomically and agroecolologically sustainable livelihood options.

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Appendix 1 – Fertiliser price adjustment for inflation

Real price = Current year retail price*(1963 CPI/ current year CPI adjusted to 1963 CPI)

CPI adjustment in 1998 and 2003, taking 1997 and 2002 base prices respectively as 100 meant 1998 and 2002 CPI was adjusted to 1963 base price using

Current year CPI relative to 1963 base price = (Current year CPI/100)*1997 CPI relative to 1963 price

2007-11 CPI was adjusted to 1963 base price using

Current year CPI relative to 1963 base price = (Current year CPI/100)*2002 CPI relative to 1963 price

Appendix 2 - 2010 interview topic guide

Introduction

Name

Father's name

House

Family position

Occupation

I want to talk about your farming in general and this field in particular and how you fertilise it.

Farming

Acreage, crops

Locations in relation to this field

This field

- Cropping history and intentions
- Soil -good and bad patches
  - -water retention and nutrients

Fertilisation

Throughout your fields

- On this field in particular
- Transportation of different fertilisers
- History of fertilisation on this field

Reasons

- Why use different SFM techniques
- Opinions of efficacy – 'efficient', 'cheap', 'useful', 'easy', 'effective'
- Pros and cons of different methods

Reasons for changes of SFM/IMT techniques

Lessons learnt from past experiences/experiments

Different pros and cons for different user groups

Individual and group ownership

Opinions

Expectations of participation -benefits

-risks

Predictions of findings

Importance of *kulum tam* and *benzirra* to everyday life

Findings thus far -time

-labour

-cash

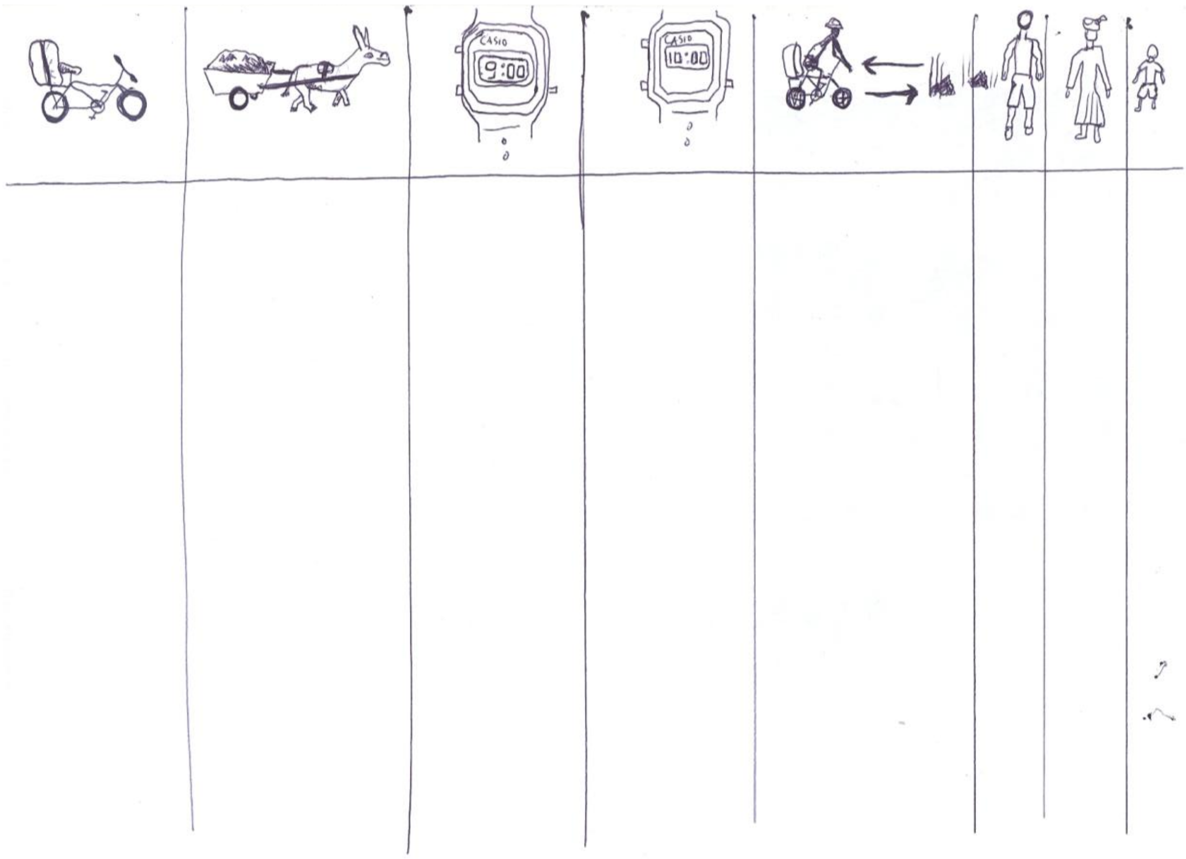
-social capital, teamwork

-social appearance

Walk around field and take GPS, identify good and bad patches, ask reasons for, effects of and comments about gradient, catena, different soil colour, grass characteristics, crop patterns etc.

Appendix 3 - Carriage record sheet

An example of the carriage record sheet for a farmer using donkey and bicycle. Sheets were personalised with the particular mode of transport each farmer used.



Appendix 4 - Calculations of conversion of carriage parameters into adjusted units

$$\text{Volume compost carried per personhour} = \frac{\text{volume compost carried (m3)}}{(\text{number people carrying } \times \text{ hours spent carrying})}$$

$$\text{Volume compost carried per ideal personhour} = \frac{\text{volume compost carried (m3)}}{(\text{minimum number people necessary to carry } \times \text{ hours spent})}$$

$$\text{Volume compost carried per personhourkm} = \frac{\text{volume compost carried (m3)}}{\left(\left(\text{number people carrying } \times \text{ hours spent}\right)\right)} \times \text{distance from farm to compost(km)}$$

$$\text{Volume compost carried per ideal personhourkm} = \frac{\text{volume compost carried (m3)}}{\left(\left(\text{minimum number people necessary to carry } \times \text{ hours spent}\right)\right)} \times \text{distance from farm to compost(km)}$$

Appendix 5 - Census questionnaire

Asked for every member of every house

Question	Answer codes
Approximately how many years old is their house?	
Does it have cement inside?	0=no, 1=yes
Does it have a zinc roof?	0=no, 1=yes
What is their name?	
What is their house name?	
How are they related to the landlord?	
Do they know their age? If not, guess	
Do they have any work? If so, what?	0=just farming 1=vegetable production 2= anything else
How many cows do they own?	
How many goats?	
How many sheep?	
How many chickens?	
How many guinea fowl?	
Do they have a bike? If more than one, how many?	
If so, what type?	
Do they own any other benzirigu? (truck, wheelbarrow, donkey or bullock cart)	0=no, 1=yes
Did they go to school?	0=no, 1=yes
Are they a member of any group?	0=no, 1=yes
Do they have their own farm?	0=no, 1=yes
How many people help them carry compost to the farm? Who are they?	
Can they themselves help others carry compost to the farm?	0=no, 1= yes if a child or woman 2=yes if a man

Appendix 6 - Qualitative soil tests

Adapted from USDA 2001 Soil Quality Test Kit Guide, Agricultural Research Service, Natural Resources Conservation Service and Soil Quality Institute

1. Dry soil colour test

   Compare dry soil to Munsell chart

2. Wet soil colour test

   Moisten soil and compare to Munsell chart

3. Soil structure

   Adapted from p.24 - Determine if soil peds and aggregates are granular, blocky or platy
   Adapted from p.25 - Note size of aggregates or peds
   Adapted from p.26 - Note grade as weak, moderate or strong by observing if peds break when crushed weakly or forcibly

4. Texture

   Adapted from p.27 - Use texture by feel procedure to determine extent of clay, sand and silt

5. Slake test

   Adapted from p.20-21- Carefully remove soil fragments or aggregates from the soil surface.

   • Fill a tray 2cm deep with rain water approximately the same temperature as the soil.

   • Place soil fragments in a sieve basket.

   • Lower the sieve basket into the water.

   • Observe the soil fragment for five minutes. Refer to the stability class criteria to determine classes 1 and 2.

   • After five minutes, raise the basket out of the water, then lower it to the bottom. It should take one second for the basket to clear the surface and one second to return to the bottom.

   • Repeat immersion four times (total of five immersions). Refer to the stability class criteria to determine classes 3 through 6.

Criteria for assignment to stability class:

0 - Soil too unstable to sample (falls through sieve).

1 - 50 % of structural integrity lost within 5 seconds of insertion in water.

2 - 50 % of structural integrity lost 5 - 30 seconds after insertion.

3 - 50 % of structural integrity lost 30 - 300 seconds after insertion or < 10 % of soil remains on the sieve after 5 dipping cycles.

4 - 10 - 25% of soil remaining on sieve after 5 dipping cycles.

5 - 25 - 75% of soil remaining on sieve after 5 dipping cycles.

6 - 75 - 100% of soil remaining on sieve after 5 dipping cycles

6. Topsoil profile

   Describe structure and shape of topsoil aggregates

7. Root density in $100cm^2$ profile

   Cut a $10cm^2$ slice into the soil profile. Remove debris and count roots in the profile.

8. Max. root thickness

   Measure the thickest root in the profile

9. Max. root branches

   Adapted from page 23 - Count the maximum number of branches in the profile.

Appendix 7 - Soil nutrient tests

pH

The meter was standardised with a pH 4 and a pH 7 buffer. A 10g sample was passed through a 2mm sieve and mixed with 25m distilled water, stirred and left to stand for 30 minutes before being stirred again and read with a meter.

C, Walkey Black method

An approximately 1g of known weight was passed through a 0.5mm sieve and mixed with 10ml 1M potassium dichromate. 20ml of conc. H_2SO_4, 100ml of dH_2O and 1ml Orthophosphoric cid was added and 2-3 drops of diphenyamine indicator was used in the titration with 0.5M Fe(II) SO4.

Total N, Kjedahl method

An approximately 1g of known weight was passed through a 0.5mm sieve and added to a digestion mixture of lithium sulphate and selenium powders and conc. H_2SO_4. 10ml of this was brought to 360°c and digested for 5-6 hours until clear before being brought to 100ml with dH_2O. $H_2O_2$was added to clear the colour of any recalcitrant indigestible organic matter. 20ml of 40% NaOH was added to a 20m aliquot. This was evaporated, condensed and passed through 5M Boric acid which was then titrated with 0.2M HCl.

Available P Bray-1

1.0g soil was passed through a 2 mm sieve. 35ml Bray solution was added and the mixture was shaken for 8-10 minutes and filtered. Ammonium Molybdate and ascorbic acid was added and the mixture was read at 850nm in a spectrophotometer.

Exchangeable K

5 g soil was extracted by shaking with 50ml ammonium acetate for 2 hours and then filtering. The mixture was read at 760nm on a flame photometer.

Appendix 8 - 2010 questionnaire

Question	Answer codes
Whose farm is this really?	
What types of transport did you use to carry compost to the farm this year?	1=headpan, 2=bicycle, 3=wheelbarrow, 4=trocko, 5=donkey, 6=bullocks
Who exactly used each of those vehicles to carry the compost?	Note individual and relationship to respondent
When you used each of those vehicles, what advantages were in it?	1=cheap, 2=fast, 3=large amount, 4=available at any time, 5=used at any time, 6=needs few people, 7= anyone can use it, 8=little effort, or other
When you used each of those vehicles, what disadvantages were in it?	1=expensive, 2=slow, 3=small amount, 4=have to wait to use it, 5=specific time for use, 6=requires many people , 7=only specific people can use it, 8=requires much effort, 9=can spoil, 10=can injure you , 11=if illness occurs can't use it, 12=associated tools like shovels are not available, 13=not available in this village, or other
Of all the benzirra, which has advantages above all the others?	
Which next? Until – which last?	
Above, you said the disadvantages of benzirra x were y. What could help you solve that problem? Repeat for each problem mentioned.	1=more money, 2=more men, 3=more women, 4=more children, 5=more time, 6=more knowledge, 7=being in a group 8=no solution, or other
You use group/ your own/ hired benzirra. Which did you prefer?	1=group , 2=own, 3=hiring
If you preferred.... why did you also use....	
How much do you think it is reasonable to pay for 1 trip using the bullock cart?	
How much do you think it is reasonable to pay for 1 trip using the donkey cart	
This year, what have you done to make sure your farm is fertile ?	1=15:15, 2=ammonia, 3=23.10, 4=compost, 5=manure, 6=tampooli, 7=dynamic kraaling, 8=crop rotation, 9=fallowing, 10=double ploughing, 11=not burning, 12=green manure, 13=herbicide, 14=mixed cropping, 15=pollarding, 16=weeding, 17=ridging, 18=mulching
How many bags of each type of fertiliser?	
Bought or loaned?	
How much did each cost?	
Was each SFM technique done in this farm?	

Was it done in another?	
Of all, which was most useful?	
Which second most useful?	
Which third most useful?	
Next year, which would you like to use to make sure your farm stays fertile?	
What would you need to help you do that?	1=more money, 2=more men, 3=more women, 4=more children, 5=more time, 6= more knowledge, 7=being in a group 8=no solution, or other
Earlier you said ......was the best form of transport. Would you also need another one to help you keep your farm fertile or to help you do the SFM techniques you would like to use next year? If so which?	1=headpan, 2=bicycle, 3=wheelbarrow, 4=trocko, 5=donkey, 6=bullocks, 7=tractor, 8=power tiller, or other
Have you learnt anything new about compost this year? prompts – when to make it, when to take it to the farm, about storing it, about the area to apply it to	
Looking at the farm – where has it done well and not so well? Why? When did you apply fertiliser? If late, why? Why did you apply 2 or 1 type of fertiliser? Why apply compost to that area? Is compost or fertiliser area better? Why? Confirm last year's crop Confirm soil types	
Check the farm map for questions specific to this farm based on observation throughout the season	
Do you want to add anything?	

Appendix 9- 2011 questionnaire

How much compost did you carry this year using each vehicle?

To which crops did you carry it?

Have you changed anything about how you compost this year?

What do you think about the group in general?

What are the problems you have experienced being in the group?

What could you do to solve those problems?

Is it possible to have a group owning cattle in the same way as we had a group owning the donkey?

What are the differences between cows and donkeys in Dagomba tradition?

What are the differences between cows and donkeys in their work?

Can individuals borrow the cattle of their household members?

Under what circumstance could they be forbidden from doing so?

Is compost more for cash or food crops?

Who uses compost in your house and for which crops?

Appendix 10 - Recommended MOFA fertiliser application rates

15:15:15 – 2x50kg sacks per acre 3 – 7 days after emergence. To be followed by Sulphate of ammonia at tasseling period

Sulphate of ammonia – 1x50 kg sack per acre at tasselling period

23:10:5 – 2x50kg sacks per acre 3-7 days after emergence. Stands alone without ammonia application

Appendix 11 - Rainfall data

Source: Savanna Agricultural Research Station, Nyankpala, 15 km west of Ypilgu.
Precipitation (mm)

2007												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1					38.4				trace			
2						36.7						
3						1.1			49.5			4.1
4										2.1		
5										1.2		
6												
7										trace		
8			8					48.2		14.3		
9												
10								1.5	10.5			
11						trace		0.5				
12				6.4			31.8	8	1.2			
13					54.1			8.5				
14					0.5			9.8	1.2			
15									0.7			
16					0.4	7.6	5.5	7.4	17			
17							31.1	39				
18					27.5			4.7				
19					6.5				42.3	13.3		
20								2.3				
21				14.9			14	10.6	15	3.5		
22						14.3	16.7					
23					3.3	8.3			23			
24								2.8				
25							21					
26								7.8		13.9		
27					5.2		39.4	20.4				
28							1.2	17.4	24			
29			36.4		0.9			trace	trace			
30				3.2								
31			39.4					126				
monthly totals	0	0	83.8	24.5	136.8	68	160.7	314.9	184.4	48.3	0	4.1
annual total												1025.5
dry spells>6 days						2	0	1	1			

2008												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1								22.5				
2				23.7								
3							15.4	13.5	28.1			
4							10.5					
5						2.3	0.8	22.8	19			
6						7.8			15.5			
7							17					
8				0.7			10.6					
9					16							
10						3.8			12.3			
11		32					14.5		17			
12		3.7		69.4	26.3		1.9	26.5				
13				0.5	26.4		21.6		8.8			
14					0.1		8.6					
15							34.4		0.7			
16												
17					21.5		1.4		15.8			
18			52	25	2.4	29.9		14	2			
19								2.4				
20				51		2.5		3.7		0.3		
21		8.8				21.4	55		19.1			
22						11	0.5					
23				6.2	6.5		11.5	1				
24			18.2	11.3	0.7	8.9	trace	2.3				
25					1.8	61.9		41.1				
26			5.1									
27			trace	5.5				37.3				
28					17.4		65.3					
29					1.8		82.4					
30					3.3	2		0.9				
31				0.9		37.3						
monthly totals	0	44.5	75.3	194.2	124.2	188.8	351.4	188	138.3	0.3	0	0
annual total												1305
dry spells>6 days						1	0	1	1			

2009												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1				36.8			48.8		93.5			
2												
3					12			8.5				
4						14.6						
5							10.2	55				
6									84			
7						18			2.3			
8									19.2	35		
9							15.3	9.9	3.5			
10									0.3	3.3		
11				28.4								
12									19.8			3.2
13								7.3				
14					17.3	27.4			21.8	15.1		
15				5.5		15.3		30.9		6.3		
16		6.7						57.1				
17			11.2		9.5							
18							30.9	25.2				
19			8.6									
20				21.1			22	9.1	12.5	9.2		
21					18.6	5.9			3.9			
22							2	15	20			
23									16	6.7		
24								2.9				
25				10.3			53.1					
26									39.7			
27				3.1	12.7		14.4	60.5		55.3		
28						7.7			9.3			
29				13.6		5.3						
30							90					
31												
monthly totals	0	6.7	19.8	118.8	70.1	94.2	286.7	281.4	345.8	130.9	0	3.2
annual total												1357.6
dry spells>6 days						2	1	0	0			

2010												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1						trace			34	12.5		
2									2.4			
3						46.1			3.9	8.5		
4										15.6		
5				2.7			12		2.6			
6					1.4				0.6	3.3		
7								34.7	2.3	2.2		
8							45.3	27.3	18.6			
9						7.3		2.8				
10								34.8				
11			3.2				27.1	0.6	1.6	2.9		
12								94.2		33.7		
13		70						1	6.5			
14								5.8	10.7	5.6		
15				23.1			2.2		0.7			
16				29.1		74.3	2.9	14.5				
17			38.2				2.4		2.8			
18										13.1		
19					11							
20						21.4		46.2	40.5			
21												
22				52.2			21.5	11.3	10.5	3.8		
23							5	1.3	8.5			
24				46.2		22.2			11.9	9.1		
25						8.3				9.2		
26				42.4		0.9		28.3				
27				0.2			8.8		13.1	10.2		
28						0.4			7.8	17.9		
29					8.6		2.5					
30								23.7	5			
31							3.2	4.3		9.2		
monthly totals	0	70	41.4	195.9	21	180.9	132.9	330.8	184	156.8	0	0
annual total												1313.7
average												
dry spells>6 days						2	1	1	0			

2011												
Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1												
2					8.7			84.3				
3		5.6					28.6		10.1			
4				1.3		16.1		9.8		28.3		
5								0.7		3		
6									52	2.4		
7						9.3		41.1		3.5		
8					19.4			4.8	13.5	2.5		
9							15			9.7		
10				17.1			23.8	12.9	15.9			
11					0.6				13.4			
12						1.3						
13								1.4	trace	32.6		
14					0.8	39.9	0.5	26.2		20.4		
15							15.6	0.3				
16									28			
17					5.8	4.8	24.4					
18												
19						3.3	14.8		3			
20									48.6			
21			trace									
22								1.1				
23				35.2		126.7						
24						17.2		5.3	0.6			
25									0.2			
26					3.8	6			3			
27									0.2			
28								0.8	3			
29						3.1	23					
30					13.8	23.9		23	18.8			
31								44				
monthly totals	0	5.6	0	53.6	52.9	251.6	145.7	255.7	210.3	102.4	0	0
annual total												1077.8
dry spells>6 days						0	1	0	0			

Appendix 12 - Supplementary outputs

Papers

Bellwood-Howard, I. (2012). *Donkeys and bicycles: Capital interactions facilitating timely compost application in Northern Ghana*. International Journal of Agricultural Sustainability 10 (4) 315-327.DOI: 10.1080/14735903.2012.666030.

Bellwood-Howard, I. 2012 *Reflections on teaching and learning scientific methods in the Ghanaian field and the English classroom.* School Science Review 346, 85-91

Video and film

A 15-minute documentary about the work in this thesis, *'Ghanaian compost and donkeys',* can be seen at http://www.youtube.com/watch?v=YgOCFJVBH1o.

A 6-minute version is seen at http://www.youtube.com/watch?v=JnnKpDCUFzU&context=C33aadbeADOEgsToPDskLMZ-zHZXdvpbJQ7MW7Yacs

A compost training manual*, 'Kulum Tam Niŋbu' ('Doing compost')*, made by participant farmers and researcher, is found at https://vimeo.com/58787655#at=NaN

Two feature films based on the work, *'Konga mali o saɣidirili ('Cut your coat according to your size')* parts 1 and 2, are linked to through https://sites.google.com/site/ibellwoodh/home/videos

Pamphlets

Three compost production pamphlets drawing on participant farmers' practical findings are seen at https://sites.google.com/site/ibellwoodh/home/pamphlets

Conference papers

The following conference papers are also linked to through https://sites.google.com/site/ibellwoodh/home/presentations

Bellwood-Howard, I. *Research and dissemination methods for non-literate contexts*. 6th Harmattan School Conference, Ghana Institute of Literacy, Language and Translation, Tamale, Ghana. 7th February 2012. http://www.uds.edu.gh/cceir/Bellwood-Howard,%20Research%20and%20dissemination%20methods%20for%20non%20literate%20contexts.pdf

Bellwood-Howard, I. *Access systems to sustainable compost transport in Ghanaian Savanna smallholdings*. 18th International Sustainable Development Research Conference, University of Hull, UK. 25th June 2012. http://media.isdrs.org/2012/08/isdrs-nl-issue2-2012.pdf

Bellwood-Howard, I. *Community scale organisation gives Northern Ghanaian smallholders access to farm vehicles*. Royal Geographical Society Conference, University of Edinburgh, UK. 3rd July 2012. https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxpYmVsbHdvb2RofGd4OjU1Njk5NmMzZjAwYzU0M2M

Bellwood-Howard, I. *Participant observation as a tool for holistic agroecosystems research.* 32nd International Geographical Congress, University of Cologne, Germany. 28th August 2012. http://prezi.com/i4b9qdgf5cmt/participant-observation-as-a-tool-for-holistic-agroecosystems-research/